

Wet-weather Management of OHV Trails on National Forests in California



prepared for

USDA-Forest Service, Pacific SW Region, Vallejo, CA

by

Roger Poff

R. J. Poff & Associates, Nevada City, CA

September 30, 2014

under

Professional Services Contract AG-91S8-C-10-0027, Natural Resources Management Corporation, and Work Agreement U30-12-15, USFS Enterprise Unit Trails Unlimited

Table of Contents

1.0 Introduction.....	1
2.0 Wet-Weather Management.....	1
2.1 Seasonal Closures.....	1
2.2 Precipitation-based Closures.....	2
2.3 Evidence-based Closures.....	2
3.0 Basic Concepts of Trafficability.....	2
3.1 Soil Compaction, Puddling, and Rutting.....	3
3.2 Beneficial Effects of Motorized Traffic.....	3
3.3 Infiltration and Permeability.....	3
3.4 Concentration of Runoff.....	3
3.5 On-site vs. Off-site Impacts.....	4
3.6 Sediment Delivery to Watercourses.....	4
3.7 Wetting and Drying Fronts.....	4
3.8 Resource Damage and Wet-weather Traffic.....	4
3.9 Management Tools and Strategies.....	6
4.0 Methodology.....	7
4.1 Assessments.....	7
4.2 Pilot Study Areas.....	7
4.3 Data Collection.....	9
4.4 Data Analysis.....	10
5.0 Results and Discussion.....	11
5.1 Assessments.....	11
5.2 Pilot Studies.....	12
5.3 Techniques and Equipment.....	13
5.4 Other Results and Discussion.....	14
5.5 Need for Future Study.....	16
6.0 Conclusions and Recommendations.....	16
7.0 References.....	17

Appendix 1 Trafficability Assessment

Appendix 2 An Evidence-based Process for Wet-weather Closures on the Pozo Area,
Santa Lucia RD, Los Padres NF

Appendix 3 An Evidence-based Process for Wet-weather Closures on the Stonyford
Area, Mendocino National Forest

Appendix 4 An Evidence-based Process for Wet-weather Closures on the Upper Lake
Ranger District, Mendocino National Forest

Appendix 5 An Evidence-based Process for Wet-weather Closures on the Sugar Pine
OHV Area, Tahoe National Forest

Appendix 6 Data Collected and Scatter Diagrams

Appendix 7 Acknowledgements

1.0 Introduction

This report documents the results of a three-year study of wet-weather management of OHV trails on National Forests in California. The study was funded under a grant from the California Department of Parks and Recreation, OHV Division, with matching funding from the U. S. Forest Service.

The objectives were to assess wet-weather management strategies in use on National Forests in California, and specifically to investigate and field test an evidence-based method for opening and closing trails based on soil trafficability.

The method is based on work originally done on the Stanislaus NF that was further tested and developed on the Sam Houston NF in Texas and the Wolf Pen Gap area on the Mena Ranger District in Arkansas. Under this contract, field testing in California was conducted on the Pozo Area of the Santa Lucia RD on the Los Padres NF, on the Stonyford area of the Grindstone RD on the Mendocino NF, on the Upper Lake RD of the Mendocino NF, and on the Sugar Pine OHV area on the American River RD of the Tahoe NF. Appendix 7 provides a list of people who have supported or participated in this work.

The method provides an alternative to seasonal or precipitation-based trail closures to protect trails from damage during wet weather. It is not intended to replace these closure methods—although it could—but provides an additional tool for the OHV manager to use in managing OHV trails under wet conditions.

The first section of this report defines the problem, discusses the advantages and disadvantages of various closure criteria, and explains basic concepts of soil mechanics and trafficability. Much of this section was originally written for the work done in Texas (Poff, 2012). This is followed by a description of how the method was tested in California, a discussion of results, and recommendations for future work.

Appendix 1 contains detailed instructions on how to implement the evidence-based trafficability method; Appendices 2 - 5 are implementation schedules for each of the four pilot study areas; and Appendix 6 contains a table of the data collected and the graphs used to analyze the data. Appendices 1 - 5 are written as stand-alone “how-to” documents and repeat or cover in more detail some of the material in this report.

2.0 Wet-Weather Management

The purpose of wet-weather trail management is to avoid damage to trails and other resources. When soils are wet, traffic on OHV trails can damage the trails. One solution is to close the trails when soils are wet. However, deciding when to close or open trails has been a challenge for OHV managers. Several methods are being used to make these decisions, but all have shortcomings.

2.1 Seasonal Closures

The most commonly used method to limit OHV traffic under wet conditions is a seasonal closure. However, dates set for opening and closing trails vary within Region 5. Seasonal closure dates are based on long-term averages of the first fall rainfall and when soils typically dry out in spring. In California, long-term averages are not very useful because fall and spring conditions vary so much from year to year. With seasonal closures the assumption is that trails

will also be closed outside the core closure period when necessary to protect the trails from damage.

The main disadvantages of seasonal closures are that they can restrict recreational use when moisture is optimum for tread compaction and that they can fail to provide adequate protection of the trails under wet conditions during the open season. The main advantage of seasonal closures is that they are relatively easy to administer.

2.2 Precipitation-based Closures

Precipitation-based closures provide more flexibility, and do a better job of linking closures to actual on-the-ground conditions, than do seasonal closures. However, precipitation-based closures also have limitations.

There are two main problems with precipitation-based closures. First, the number and location of rainfall gauges is often not adequate to capture the variability within a trail system. Second, rainfall is not directly correlated with soil moisture in the trail tread. Many variables affect how much moisture is actually absorbed by the trail tread. In addition to the amount of rainfall, how much actually soaks into the tread is affected by storm intensity and duration; antecedent moisture; drying conditions; adjacent vegetation and evapotranspiration; temperature, wind, and humidity; and water movement through the treads. Also, precipitation is not a good indicator of the effects of traffic when there is snow and frost on the tread.

Protecting drainage structures from damage is the goal of managing trails in wet weather. Closures based on precipitation are effective only to the extent that they protect drainage structures.

The amount of rainfall that makes drainage structures and treads susceptible to damage is affected by soil type, soil strength, antecedent rainfall, storm intensity and duration, rate and time of drying, and the amount and type of OHV traffic. Because of these variables, it is difficult to make a direct correlation between rainfall and the potential to damage OHV trails—especially the potential to damage drainage structures.

A variation on precipitation-based closures is to close trails based on predicted rainfall. This is an additional strategy that needs to be considered. Depending on the type of storm system, this may work in some places, but weather forecasts are not totally reliable.

2.3 Evidence-based Closures

There is an alternative to seasonal and precipitation-based closures—and that is to base closures on conditions of the trail tread itself (Janicki, 1998; Poff, 2010). It is on the trail tread and drainage structures where traffic causes damage. The method evaluated and described in this report is “evidence-based” because it is based on a correlation of soil strength and soil moisture with actual observed trail damage. The method is not arbitrary; it is based on principles of soil mechanics and can be replicated.

3.0 Basic Concepts of Trafficability

In order to understand the logic of using an evidence-based trail closure to manage OHV trails during wet conditions, it is necessary to understand how traffic damages trails when they are wet. The following discussion provides this background.

3.1 Soil Compaction, Puddling, and Rutting

Soil consists of about half solid particles and half open spaces, or pores (Mitchell & Soga, 2005). Compaction can be thought of as squeezing the air out of the soil. Compaction occurs when soil pores are partially filled with water and partially filled with air. As soils compact, pore volume decreases, density increases, and soil strength increases. Compaction cannot occur when all the soil pores are filled with water, that is, when the soil is saturated. When saturated, soil has low strength and low bearing capacity. Puddling and rutting occur when soil is saturated (Alexander & Poff, 1985).

Compaction of native-surfaced trails is desirable. Well-compacted treads hold up under traffic, and are less susceptible to displacement and soil loss by dusting when soils are dry. Drainage structures (drain dips)¹ must be well compacted to hold up under traffic. To achieve maximum density and strength it is necessary to construct and maintain drain dips when soils are at optimum moisture (Poff & Ryan, 2001).

3.2 Beneficial Effects of Motorized Traffic

Vehicle traffic can help compact trail treads. This compaction occurs when soils are moist but not saturated. The optimum moisture content for compacting treads is just a little below saturation, when soil strength is low, but when some pores are air-filled and can be compacted (Poff & Ryan, 2001).

3.3 Infiltration and Permeability

Soil infiltration and permeability affect how trails respond to rainfall events. Infiltration is the rate at which the soil absorbs water at the surface. Permeability is the rate at which water moves through the soil. The amount of water the soil can absorb during a rainfall event is also affected by existing, or antecedent, soil moisture. Antecedent moisture is the moisture in the soil from previous rainfall, and is affected by the drying conditions and length of time since the last rainfall.

3.4 Concentration of Runoff

Trails are linear features that concentrate water. Tread erosion is the major cause of deterioration on native-surfaced trails, and the primary cause of tread erosion is concentrated runoff flowing down the trail. The power to erode increases as runoff volume accumulates (Parker, 2004).

During and just after a rainfall event, water concentrates on trails in three ways:

Rain falling directly on treads. This water accumulates and flows down the tread (except where the trail is completely flat). Where drainage structures are spaced too widely, rain falling on the trail itself can accumulate and overwhelm drainage structures.

Subsurface lateral flow. On slopes with slowly permeable subsoils, rainfall absorbed by the surface soil migrates laterally downslope as subsurface flow (Richardson, Arndt, & Montgomery, 2001). This water can be intercepted and concentrated by trails.

¹ These drainage structures have been called “OHV Rolling Dips” or “Rolling Dips” in other reports. The current terminology, “Drain Dip,” is used in this report.

Runoff from impervious surfaces. Nearby roads and trails can concentrate rainfall and drain it onto a slope above a trail or directly onto a trail. Soils that are shallow to bedrock also have high runoff.

Of these three, runoff from impervious surfaces is the most serious. This is because the volume of water delivered from impervious surfaces can be large. Large volumes of water are also involved where trails capture ephemeral drainages.

It is important to note that concentrated runoff causes tread erosion with or without vehicle traffic, although traffic can loosen the soil and accelerate erosion.

3.5 On-site vs. Off-site Impacts

Wet-weather damage to trails and associated resources occurs both on site and off site. On-site impacts are impacts to the trail itself. Rutting, damage to drain dips, and loss of tread by displacement and erosion are examples of on-site impacts. On-site impacts can occur anywhere on the trail system.

An example of an off-site impact is when soil eroded from the tread is delivered as sediment to a watercourse. Off-site impacts occur where trails are hydrologically connected to watercourses (Furniss, Flanagan, & McFadin, 2000). Hydrologic connectivity is greatest at or near watercourse crossings. Another off-site impact occurs when concentrated runoff erodes the slope below a trail. This can occur with or without sediment delivery to a watercourse.

3.6 Sediment Delivery to Watercourses

Wet-weather traffic at and near watercourse crossings—especially on the approaches to crossings—detaches soil from the tread. This soil is readily transported as sediment to the watercourse. Properly designed watercourse crossings can mitigate the potential for sediment delivery (U. S. Forest Service, 2011).

3.7 Wetting and Drying Fronts

The susceptibility to damage from traffic in wet weather is affected by the depth of wetness in the tread. In a wetting front the tread is wet or moist at the surface, but dry below. This occurs when the top few inches of the tread have been wetted up by a recent storm. In California, a wetting front typically occurs during the first few fall storms at the beginning of the rainy season. Trails can dry out between storms by surface evaporation, gravity, and absorption by the drier soil below. The dry subsoil has good bearing strength, so damage is usually limited to an inch or less of the surface tread. The risk of tread damage is generally low under a wetting front.

In a drying front the tread is dry at the surface, but wet or moist below. This typically occurs at the end of the rainy season in late winter and spring. Drying occurs slowly because the wet subsoil constantly replenishes the moisture lost by drying at the surface. If the dry surface layer of the tread is too thin or weak, traffic breaks through, creating deep ruts. Also, heavy traffic can “pump” subsurface moisture to the surface (Edwards, 2011). This weakens the running surface, allowing traffic to break through it. The risk of damage to treads and drainage structures is high under a drying front.

3.8 Resource Damage and Wet-weather Traffic

Resource damage related to wet-weather traffic can be grouped into three broad categories: damage to drainage structures; rutting and tread erosion; and sedimentation. These categories differ in processes, causes, and types of treatment.

Damage to Drainage Structures

The most serious impact of wet-weather vehicle traffic is damage to drainage structures (Poff, 2006). Failed drainage structures lead to tread loss by erosion, and increased sedimentation, especially during major storm events. Wet-weather closures are primarily effective to the extent that they protect drainage structures.

The potential for damage to a drainage structure depends on the soil strength of the structure. The strength of the structure is a function of how well it was compacted when it was constructed or maintained, and of its current moisture status. Moisture status is affected by structure design and construction, how the structure has been maintained, and how much moisture the structure has absorbed and retained since the last rainfall.

Drainage structures affect both on-site and off-site impacts.

Most rainfall will run off a well-constructed drainage structure and not be absorbed into it. This means that intense storms of short duration are less likely to wet up drain dips and make them susceptible to damage. However, when storms are more frequent and lower in intensity, drainage structures are more likely to absorb moisture and lose strength.

Tread Erosion

Tread erosion is the result of water concentration, which is caused by a lack of adequate drainage. Vehicle traffic is an indirect cause of tread erosion when it damages drainage structures to the extent that they no longer divert runoff from trails.

The impact of tread erosion is less obvious than damage by rutting. However, tread erosion can be more serious in the long term. Loss of tread can eventually lead to deeply entrenched trails that are no longer sustainable because they cannot be effectively drained or have become too rough for the designated use.

Rutting and Pumping in Treads

Ruts develop when treads are wet and have low strength. Ruts can concentrate runoff, even on trails with low gradients. This can lead to gully erosion, especially if the rut breaks through the compacted running surface to the less compacted subsoil.

Ruts can also result from pumping (Edwards, 2011; Meyer, 2002). Pumping occurs when the surface tread is dry but the subsurface is wet. The action of continuous traffic—such as during an event with a lot of traffic in a short time period—draws moisture to the surface, reducing soil strength. When the surface tread no longer has the strength to bear the traffic, vehicles break through the surface, causing rutting. Rutting caused by pumping generally occurs on the flat sections of trail that tend to hold moisture.

Wet Areas

Water can accumulate in flat areas and/or be perched close to the surface. Since wet soils have low strength, wet areas are subject to deep rutting. Extensive braiding can also result when riders avoid wet soils and ruts seeking firmer soils. Wet areas typically occur on soils high in clay, which dry out slowly.

Where rainfall is the source of moisture in wet areas, soils can dry out between storms, although it may take some time. However, where wet areas have a perched water table, or are wet because of a seep or spring, they can remain wet throughout most of the year.

Trails through broad wet areas often become widely braided and deeply rutted. Where possible, trails should be rerouted to avoid these areas. If there is no alternative but to cross a

persistently wet area, techniques using rock, geotextiles, and other materials can be used to create a tread that can withstand wet-weather traffic (Meyer, 2002).

Potholes, Puddles, and Downed Logs

Water can accumulate in low spots on trails as puddles. The puddles lead to trail widening by braiding where riders leave the trail to avoid the puddles.

Except for trail widening, potholes and puddles are more of a nuisance than a threat to trail sustainability. Traffic through potholes can displace soil from the tread when muddy water is splashed onto the edge of the trail, but this soil is not lost from the site and can be reclaimed.

Downed logs across trails can also cause braiding and rutting. New routes created to get around downed logs are often deeply rutted because undisturbed soils adjacent to trails are not compacted, and are highly susceptible to rutting when wet.

The braiding at potholes and downed logs can be mitigated by draining potholes and clearing logs during trail maintenance.

3.9 Management Tools And Strategies

The potential for resource damage by wet-weather use of trails depends on several factors. A trail manager has no control over the soil type or the precipitation, but trail location, trail layout, drain dip spacing and design, watercourse crossing design, trail maintenance, and traffic regulation are all tools that can be used to manage the impacts of wet-weather use. Note that closing trails is only one of several tools available to manage trails for wet-weather use.

The following management tools and strategies are important in managing trails for wet-weather use, whether the closure is seasonal, precipitation-based, or based on trafficability.

Trail Location

Location is important in several ways. Trails can be located—or relocated in the case of an existing system—to avoid soils that are chronically wet and have low strength.

Trail Layout and Design

Trail layout is important for many reasons, but especially for providing effective drainage. Proper layout can avoid long sustained gradients and trails down the fall line, and can incorporate breaks in grade to provide drainage. Layout also includes proper location and spacing of drainage structures (Parker, 2004). Trail design may include construction techniques for problem areas, such as using geotextiles and rock fill to cross chronically wet areas (Meyer, 2002).

Watercourse Crossing Design

Properly designed crossings minimize the effects of wet-weather use on water quality.

Crossing approaches have the highest potential for sediment delivery to watercourses. The watercourse approach is the segment of trail closest to the watercourse—more specifically, the segment of trail sloping toward the watercourse between the last waterbreak on the trail (the cut-off waterbreak) and the edge of the watercourse. Keeping the approach as short and as level as possible is the key to minimizing sediment delivery at watercourse crossings. The approaches to bridges and arch culverts are typically short and often include a reverse grade. This is one of the reasons bridges and culverts are effective in minimizing sedimentation—often more important than getting “wheels-out-of-the-water.”

Drainage and Trail Maintenance

The most important strategy in protecting native-surfaced trails from wet-weather damage is providing effective drainage. Properly located crossdrains such as drain dips disperse runoff before it concentrates and begins to erode the tread. A properly designed drain dip incorporates a catch basin at the point where runoff is diverted from the trail (Poff, 2006). The catch basin traps the soil eroded from the tread and keeps it close to the trail. This allows captured soil to be recycled back into the tread or drainage structure during maintenance. Properly designed and located drainage structures minimize erosion and sediment delivery, conserve soil by recycling it, and help keep treads drier so trails can be open longer.

Effective Management

All of the elements discussed above are important to maximize recreational opportunities in a sustainable manner while minimizing resource impacts under all conditions, but especially when trails are wet. These tools and strategies complement one another and work synergistically as a total package. Effective management also includes signing, education, monitoring, trail maintenance, law enforcement, and organizing and mobilizing volunteer groups.

It is important to re-emphasize that closing trails is only one of many tools available to manage the effects of wet-weather trail use. By itself, a closure will not protect trails or other resources from wet-weather damage. Protecting trails from wet-weather damage requires a fully integrated program of trail management.

4.0 Methodology

The methods used to develop wet-weather management tools and strategies included an assessment of current wet-weather management strategies, and four pilot studies to test using the evidence-based approach to open and close trails.

4.1 Assessments

The assessments consisted of office meetings with Forest recreation staff and OHV managers, and interviews over the phone. The assessments were done to determine what methods were currently in use to manage OHV trails under wet conditions—particularly methods for closures—and to determine the degree of interest in participating in the pilot studies.

4.2 Pilot Study Areas

The primary purpose of the wet-weather grant was to test and evaluate the evidence-based method for determining when to open and close trails under wet-weather conditions. There were two main reasons for conducting pilot studies. First, the evidence-based method had only been field tested extensively in Texas, and for application in California it needed to be tested under a different set of soil and climate conditions. Secondly, the methods and techniques used in Texas had evolved, and new equipment was available, so the methods and equipment needed additional field testing.

Time and funding constraints limited the field testing to only a few OHV areas. The final selection of the pilot study areas was influenced by the closure policies currently in use; how well each area represented regional variations in climate and soils; type and amount of OHV use; and the level of interest and support by OHV managers, line officers, and users. Each of the four pilot study areas that were finally selected met most of these criteria.

The four OHV areas selected for pilot studies are described below.

Pozo-La Panza Area, Santa Lucia RD, Los Padres NF

The Pozo area was selected to represent southern California National Forests. Average annual rainfall is about 23 inches, most falling from November through March. This typically creates on-and-off-again wet-weather conditions throughout the winter months. Wet-weather conditions are currently managed with a seasonal closure.

Soils are gravelly sandy loams and coarse sandy loams derived from granodiorite, and gravelly sandy clay loams developed in deeply weathered conglomerates (O'Hare & Hallock, 1980). Vegetation is primarily chaparral with scattered oak woodland. The topography is dissected, and canyon sideslopes are steep. Short sections of watercourses are spring-fed, but most watercourses are intermittent.

The Pozo area has about 38 miles of trails, mostly single-track suitable for advanced riders. Most trails follow ridgelines and sandy washes, but some occur on steep sideslopes. Use is primarily by motorcycles, with light use by ATVs and mountain bikes. The intensity of use is light to moderate.

The area has an elaborate system of gates that allows separating the trails from the road system during closure periods.

The area has an active group of user-volunteers who are very involved in the management of the area. The users have a high level of interest in using the evidence-based approach for determining when to open and close trails.

Stonyford Area, Grindstone RD, Mendocino NF

The Stonyford area is one of the most heavily used and intensively managed Forest Service OHV areas in northern California. Average annual rainfall is about 23 to 40 inches, most falling from November through March. This typically creates on-and-off-again wet-weather conditions during the winter months at the lower elevations. Trails at the higher elevations are typically closed by snow during the winter. The Stonyford area gets less precipitation than the adjacent Upper Lake District to the west because most storms come from the southwest and the ridge between the areas creates a rain shadow. Traffic during wet weather is currently managed using a precipitation-based closure.

Soils are mostly gravelly loams developed in residuum from metamorphic coast-range bedrock, plus areas of clay loam and silty clay loam soils at the lower elevations (USDA-Natural Resources Conservation Service, 2014). Elevation ranges from 1,700 to nearly 6,000 feet. Vegetation is chaparral and scattered Foothill pine at the lower elevations, and Ponderosa pine and mixed conifer forest at the higher elevations. The lower elevation terrain is dissected with steep sideslopes, but terrain at the higher elevations is more gently rolling. Major watercourses include Stony Creek, a perennial stream, and Little Stony Creek, which is intermittent.

The area has about 170 miles of trail suitable for vehicles less than 50 inches in width, including about 10 miles of single-track trail. Trails provide riding opportunities for beginning, intermediate, and advanced riders. Use is about 90 percent by motorcycles and 10 percent by ATVs, with more ATV use during the hunting season.

Upper Lake RD, Mendocino NF

The Upper Lake RD has an intensively managed and heavily used road and trail system. Average annual rainfall ranges from about 37 to 50 inches, most falling from October through April. This typically creates on-and-off-again wet-weather conditions during the fall and spring.

Trails at the higher elevations are typically closed by snow during the winter. Wet-weather conditions are currently managed with a precipitation-based closure.

Soils are primarily gravelly loams developed in residuum from metamorphic coast-range bedrock (USDA-Natural Resources Conservation Service, 2014). Elevations range from 1,600 to 4,500 feet. Vegetation is oak woodland with patches of brush at the lower elevations, and Ponderosa pine and mixed conifer forest at the higher elevations. The topography at the lower elevations is moderately steep, but the slopes are more gently rolling along the ridge tops at the higher elevations. Most watercourses are perennial.

The area has about 135 miles of road and trail and provides riding opportunities for novice to advanced users. Use is about 70 percent by motorcycles and 30 percent by ATVs, with more ATV use during the hunting season.

Sugar Pine OHV Area, American River RD, Tahoe NF

The Sugar Pine area is representative of OHV areas in the foothills of the Sierra Nevada. Average annual rainfall is about 54 inches, most falling from October through May. This typically creates on-and-off-again wet-weather conditions during the fall and spring. Wet-weather conditions are managed with a seasonal closure.

The area is dominated by two soil types: about 80 percent of the area has deep red clay soils developed in highly weathered volcanic bedrock, and about 20 percent has shallow, gravelly loams developed on serpentine (USDA-Natural Resources Conservation Service, 2014). Elevation ranges from about 3,000 to 5,000 feet. Vegetation is mixed conifer forest on the volcanic soils, with open stands of Ponderosa and Foothill pine on the shallower serpentine soils. The terrain is level to gently sloping, and slopes are less than 15 percent on large portions of the area. Several perennial watercourses occur in the area.

The area has about 100 miles of trail, most designated for vehicles less than 50 inches wide, but it also includes a few motorcycle-only trails. Use is about 50 percent by ATVs and 50 percent by motorcycles. The area is suitable for novice and intermediate level riders, but some motorcycle-only trails require advanced riding skills. The intensity of use is moderate to heavy.

4.3 Data Collection

Measurements of soil strength and soil moisture were made on representative soils under wetting front conditions during March and April of 2014. Because California was in a drought during 2013 and 2014, it was not possible to get a good set of data for drying front conditions.

Several segments of trail that included saturated soils were located in each of the pilot study areas. Volunteers rode through these trail segment several times (usually 5 to 10 passes) to simulate normal motorcycle traffic (In some cases the trail was being actively used and the simulated traffic was not needed.) This traffic resulted in short sections of trail with a range of trail damage from deep rutting to no observable tracks. In each segment, five sites representing very high, high, moderate, low, and very low levels of tread damage were then selected for sampling.

At each of the five sample sites, three measurements of soil moisture and three measurements of soil strength were made. Measurements were made at depths of 0 to 2 inches, 2 to 4 inches, and 4 to 6 inches. At some sampling sites measurements were not made at the 4 to 6 inch depth because of gravelly layers in the tread.

A total of 345 sets of data were collected at 14 different locations in the four pilot study areas.

Appendix 1 explains in more detail how soil strength and soil moisture were measured, and how these measurements were correlated with tread damage to predict the risk of trail damage under wet conditions. A summary of this information is repeated below.

4.4 Data Analysis

The measurements made at all the data points were entered into a spreadsheet. These data are in Appendix 6.

Following the procedures described in Appendix 1, the data points were plotted on graphs to show the relationships between soil strength, soil moisture, and tread deformation. Appendix 6 also contains the plots of the data. The graphs predict the risk of trail damage by OHV traffic at various levels of soil strength and moisture.

Since each set of three measurements was collected at the same sample point, an average of the three measurements at each sample point was also plotted for some data sets. In some cases—especially where data were collected at many sample points—this made the graph easier to read and showed the relationships more clearly. The data were also analyzed to determine the measurement depth that most accurately predicted the risk of tread failure.

Threshold values of soil strength and moisture were then developed for each pilot study area. The threshold for strength was developed by drawing a horizontal line through the cluster of

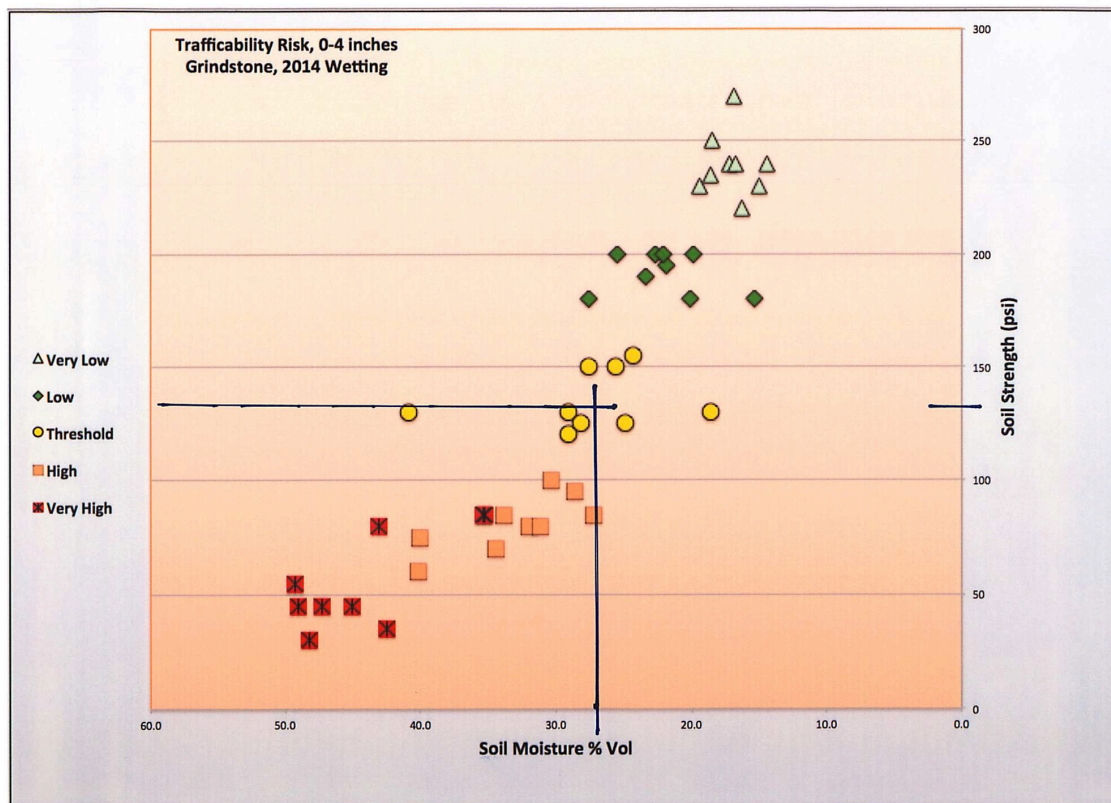


Figure 1. Example of Threshold Determination

points rated moderate; the threshold for moisture was developed by drawing a vertical line through the cluster of moderate points. In some cases, this visual method was supplemented by calculating the average values for the moderate-condition data points.

An example of lines plotted to show threshold values is shown in Figure 1. In this example, the threshold values show that when soil moisture is **greater than** 28 percent, and when soil strength is **less than** 135 psi, there is a high risk of tread damage. This high risk area is the quadrant in the lower left corner of the graph. When measurements of strength and moisture are outside of this quadrant, the risk of tread damage under normal traffic is low.

This analysis process was done for each of the pilot study areas. Because the process is empirical—based on actual field observations and measurements, not on theory or modeling—the thresholds are “evidence-based” and can reliably predict the risk of trail damage on similar soils with similar traffic. Therefore, the thresholds can reliably be used to determine when to open and close trails to avoid damage during wet conditions.

4.5 Benchmark Sites

Benchmark sites are locations within the trail system that are representative of the trail system as a whole, or that represent a portion of the trail system that can be opened or closed separately. The number of benchmark sites varied among the study areas, depending on the variability of the trail system. The benchmark sites are at permanent locations, at least during the first several years of implementing the process. This is to allow time to monitor the effectiveness of the threshold values in protecting trails and resources. Over time, the thresholds may need adjustment, additional benchmark sites may be added, and some benchmarks sites may be phased out.

On each pilot study area, initial benchmark sites were selected by working with District OHV managers and volunteers to identify sites that represent conditions of the trail system, and that have relatively easy access during wet-weather.

4.6 Triggers for Measurement

Triggers are weather conditions—typically rainfall amounts—that determine when to make measurements of soil strength and moisture. Triggers were developed by working with District OHV managers and volunteers. The triggers are slightly different for each study area, because they are based on typical rainfall events and drying periods, and on a reasonable time to allow staff to get out and make the measurements.

A decision tree was then developed for determining when to open and close trails using the triggers and threshold values of strength and moisture. Decision trees for each pilot study area are included in Appendices 2 - 5.

5.0 Results and Discussion

5.1 Assessments

After travel management planning (U. S. Forest Service, 2014) was implemented, most R-5 Forests chose to use seasonal closures to protect trails during wet weather. Only three OHV areas chose to continue using precipitation as criterion for opening and closing trails: the Upper Lake and Grindstone Ranger Districts on the Mendocino NF, and the Rock Creek Area on the Eldorado National Forest.

On the Forests using seasonal closures, the length of the closure varied considerably, as did the criteria used to determine opening and closing dates.

Under a seasonal closure, trails cannot be opened for use during the defined core closure period, but can be closed outside this core period when needed to protect trails from damage.

On the three areas using precipitation-based closures, OHV managers prefer this method—in spite of its limitations—to a seasonal closure, mainly because of the greater flexibility it provides.

5.2 Pilot Studies

In spite of the dry conditions caused by California's three-year drought, sections of trail suitable for collecting data were located on each of the study areas. The threshold values varied slightly among the pilot studies.

Study Area	Strength Threshold (Pounds per square inch)	Moisture Threshold (Percent by Volume)
Pozo Area	< 145	> 25
Stonyford Area	< 135	>28
Upper Lake District	<130	>28
Sugar Pine Area	< 140	>40

Table 1. Threshold Values for Study Areas

The threshold values for soil moisture ranged from 25 to 40 percent. This variation was caused by differences in soil types. Trails on soils derived from granodiorite in the Pozo area had the lowest threshold (25 percent by volume). The gravelly loam soils in the Stonyford area and on the Upper Lake District had slightly higher thresholds (both 28 percent by volume). The trails on the heavy clay soils in the Sugar Pine area had the highest threshold (40 percent by volume). These differences are what would be expected, given the soil textures, degree of compaction, and amount of fine gravels in the trail treads.

The differences in thresholds for soil strength (130 to 145 psi) were not as great as those for moisture. This is because soil strength is a more direct measure of trafficability. Even though the differences are smaller, they also reflect differences in soil properties. Thresholds for the Pozo area (145 psi) and the Sugar Pine area (140 psi) are slightly higher than those on the Mendocino NF (130 psi and 135 psi). Soils in the Pozo area are coarse sands, and soils in the Sugar Pine area soils are heavy clays, but both have a uniform particle size distribution. Soils with uniform particle sizes compact more readily than soils with many different sizes of particles (Alexander & Poff, 1985), and therefore tread damage starts to occur at a higher psi. The soils on the two Mendocino NF areas do not have uniform particle sizes, and have a higher gravel content, therefore tread damage starts to occur at a slightly lower psi.

These differences in thresholds among the four pilot studies illustrate that each OHV area has its own unique set of thresholds of risk. Although threshold values for soil strength generally range from about 125 to 155 psi on most trails and for most soil types, there is no universal threshold for soil strength that can be used everywhere. Threshold values for soil moisture have an even wider range. The amount and type of OHV traffic also varies from area to area, further supporting the need to develop thresholds for strength and moisture locally.

5.3 Techniques and Equipment

Condition Classes

Rating trail damage in five condition classes was an improvement over the three-class system used in earlier studies (Poff, 2012). The five classes were easy to recognize in the field and provided more precision in developing thresholds to predict the risk of tread failure.

Measurement of Moisture

In previous studies, soil moisture was measured using a tensiometer. The tensiometer takes time to equilibrate, especially in fine-textured soils and compacted treads. Five to fifteen minutes is often needed to achieve the equilibration necessary for an accurate reading. This limits the number of moisture measurements that can be made during field sampling. In addition, preparing the tensiometer for readings is time-consuming, and—if it is not used regularly—maintenance is also time-consuming. Finally, the tensiometer makes less precise measurements in wet soils, but is more precise in dry soils. For trafficability assessments, moisture is of most concern at the wetter end of the moisture range.

The HH150 moisture meter overcomes the shortcomings of the tensiometer in assessing trafficability. Readings are nearly instantaneous, the meter is simple to use, and it requires little maintenance. Moisture readings are also more precise than with the tensiometer, especially at the wetter end of the moisture range, which is important for trafficability. Although some care is needed when using the HH150 meter, on the whole it is far less complicated to use than the tensiometer. The speed and simplicity of the moisture meter allow many more measurements to be made than with a tensiometer.

The 4-pin insertion tool (actually designed for the HH2 sensor) proved to be a valuable aid in creating holes for inserting the sensor electrodes. With the center pin removed, the insertion tool can create a set of three holes. By rotating the rods one hole at a time, three different readings can be taken at the same sample point, further reducing the time to take moisture readings.

Although the HH150 moisture meter is simple and easy to use, it does have two shortcomings. First, the two electrodes on the SM150 moisture sensor are slender and sensitive to damage. Second, the control buttons on the HH150 meter are not sealed, so fine sand can get into them. Covering the meter in a plastic bag is not convenient, but might mitigate this risk.

An alternative to the HH150 meter that was considered is the HH2 meter with the ML2x sensor. This unit is a little more expensive—although not prohibitively so—but the meter is better sealed, and its four electrodes are thicker and more robust than the two on the SM150 sensor. However, a downside is that the four electrodes are more closely spaced, making insertion more difficult in gravelly soils. The main drawback of the HH2 meter for use by OHV managers and volunteers, is that it is a research-grade instrument that includes a data logger. In normal use, taking readings requires going through a complicated menu. Also, the initial set-up requires calibration for different soil types, and this requires help from a soil scientist. All of this complexity increases the risk of making errors when taking moisture readings. The HH150 meter was selected because its simplicity and lower risk of reading errors offset the slightly better accuracy and durability of the HH2 meter.

Measurement of Soil Strength

After several types of penetrometers were tested, the Humboldt H-4120HA C.O.E. Cone Penetrometer was selected because it offers the best combination of simplicity, ease of use, durability, portability, and cost. It also reads directly in Cone Index, an advantage because much of the research on trafficability is reported as Cone Index. The Humboldt HS-4210 Static Cone

Penetrometer with digital readout, used on the Pozo area, is a suitable second choice. The price is about the same for both penetrometers.

5.4 Other Results and Discussion

Variability Within Trail Systems

No matter what criteria are used for closures—whether evidence-based, precipitation-based, or seasonal—the variability within trail and road systems makes the decisions to open or close trails difficult.

Tread failure on chronically wet trail segments, or segments that retain moisture longer than most of the trail system, should not be used to close the whole trail system. These wet segments need to be assessed to determine whether they are really a problem or are just a nuisance. If a nuisance, a decision needs to be made on how much damage is acceptable. If really a problem, they could be repaired (Meyer, 2002), or the trail rerouted around them.

This variability means benchmark sites or weather stations need to be carefully selected to represent conditions across the whole trail system to support the objectives of the closure.

Drain Dip Failure

One of the most significant observations made while collecting the field data was how drain dips fail when they are too wet. The original hypothesis was that, under wet conditions, traffic would cut a rut through the top, or crest, of the drain dip structure so it no longer diverted runoff. However, it was discovered that most drain dip structures begin to fail as traffic creates ruts in the drain dip outlet. These ruts then progress by cutting into the first shoulder coming out of the dip (position S-1 in Figure 2).

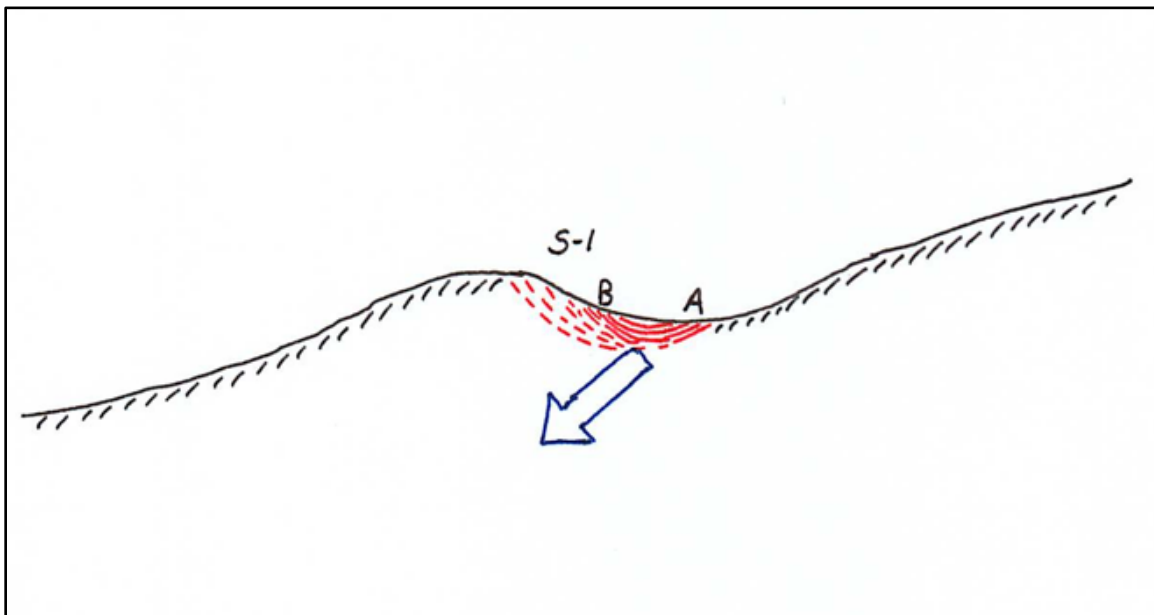


Figure 2. Wear Pattern on Drain Dip Structure

The drain dips fail in this sequence as shown in Figure 2: (1) bearing strength at the bottom of the dip is reduced by wet soils or ponded water; (2) traffic cuts a rut into the bottom of the dip at point A; (3) this rut steepens the approach angle of the convex exit shoulder at point B, and turns it into a concave profile; this causes traffic to continue to cut a rut into the exit shoulder at point S-1.

Dip structures with short and steep exit shoulders are more susceptible to this wear process. Dips constructed with a longer and more convex exit shoulder are less susceptible to this wear pattern.

The wear process described above is caused primarily by downhill traffic. Uphill traffic can also cause rutting on the shoulder downhill of the crest, but this is less common and usually occurs where the shoulder is short and steep (Poff & Groenier, 2014).

Dip Design and Maintenance

Both drain dip design and maintenance affect how susceptible drainage structures are to failure. The design factors are length of the dip structure and the dip outslope. Lengthening the distance from the dip outlet to the crest of the structure by as little as two or three feet can create a longer and more convex exit shoulder. A convex shoulder is less susceptible to wear and rutting. The outslope in the bottom of the drain dip affects soil strength at the dip outlet. When the dip outslope is less than about 3 percent, water drains more slowly from the drainage structure, or ponds at the outlet. This reduces soil strength and increases the potential for rutting.

Normal OHV traffic causes a slight berm to develop on the edges of the tread. Although this berm may appear insignificant, even a barely perceptible berm can slow the water flow—or even cause ponding—at the dip outlet. This retention of moisture reduces soil strength and leads to the rutting that initiates the failure process. Regular maintenance with a rock rake or by hand crews can remove this berm and keep the dip outlet open to reduce the risk of failure.

Partial Trail System Closures

Many trail systems include a wide range of elevations, topography, and soil types, and there are times when some portions of the trail system are suitable for riding, while other portions are too wet for traffic. Where a suitable system of gates is in place, it may be possible to close a portion of the trail system while keeping another portion open. This practice usually does not work, however, because the traffic diverted from the closed portion to the open portion increases the level of use on the open portion. Since such a partial closure would occur when moisture conditions were marginal, the extra traffic on the open portion would result in damage to it.

Partially closing a trail system has been used effectively in areas where the use level is light and the impact of diverted traffic is negligible. However, in areas with heavy use, partial closures have a high risk of failure.

Volunteer Involvement

To be successful, an evidence-based closure needs to be accepted and supported by the users. One way to gain user support is by involving them in collecting field data and in selecting benchmark sites. During the course of the field studies, volunteers and members of the Pozo area user group attended training sessions and assisted in data collection and selection of benchmark sites. Volunteers also actively participated in data collection on the Stonyford area.

5.5 Need for Future Study

Drying Front Measurements

Because of the three-year drought in California, it was not possible to collect a good set of data under drying front conditions. More work is needed to determine the best depth to measure soil moisture and soil strength in order to predict the risk of trail damage under drying conditions when the subgrade is saturated. This may not be necessary everywhere, however. For example, because of its climate, the Pozo area may rarely have saturation with depth on trail

treads. Also, trails at lower elevation areas in the Stonyford area may only occasionally reach saturation with depth.

Snow and Frost Conditions

Another issue that came up during the assessments is that precipitation which comes as light snowfall is not a reliable indicator of when to open or close trails. On the Upper Lake District, for example, snow and frost can create conditions where trail damage occurs, even though the measured precipitation indicates the trails could be open. This situation may not apply where snow has a lower water content and packs down well, but on the Upper Lake District the snow is typically slushy and not very deep. Under these conditions one or two vehicle passes is enough to create a rut in the snow that channels water on the tread, causing erosion and allowing runoff to bypass the outlets of drainage structures.

Dry Weather OHV Management

OHV traffic can also damage trails when the treads are very dry. This varies by soil type, but one concern is that dusty soils are readily washed from the trail during the first few storms of the fall rainy season and are a major source of sediment. The connection between dry-weather trail management and wet-weather trail management needs additional study.

Remote Sensing of Benchmark Sites

The Tahoe National Forest is working with the Missoula Technology and Development Center on a project involving remote sensing of data on road and trail conditions. The study site on the Sugar Pine OHV Area was selected as one of the benchmark sites for this wet-weather management project. There has been interest in coordinating remote sensing studies with the trail condition data collected using the evidence-based method.

At present, sensors for determining soil moisture need to be buried in the trail tread, because moisture and strength in the tread are not the same as in the uncompacted soil adjacent to the trail. The problem is that the potential for tread damage is related to soil moisture and strength near the surface of the tread, typically no deeper than 4 to 6 inches. Sensors placed this close to the surface are at risk from damage by normal traffic, and would have to be moved during trail maintenance. New techniques, such as using lasers that can remotely sense surface moisture, may someday overcome this limitation. This needs further investigation.

6.0 Conclusions and Recommendations

6.1 The evidence-based method can be used in California.

The pilot studies demonstrate that the evidence-based method for wet-weather management can be used in California to predict the risk of trail damage under wet-weather conditions. Compared to earlier studies, the techniques and equipment for measurement and calibration have matured and improved. The evidence-based method is a wet-weather management tool that focuses on the actual potential for damage to drainage structures (drain dips) and to the tread itself. This is a fundamental difference from using precipitation-based and seasonal closure methods to determine when to open and close trails.

6.2 Closing trails is only one of many tools for wet-weather management.

If trail drainage is not functional, trails will erode with or without traffic. Closing trails is only one of many tools for effective wet-weather trail management. For the evidence-based method to be effective, the other elements of trail management also need to be implemented.

6.3 Threshold values of strength and moisture are not universal.

Threshold values need to be developed for each OHV area and will vary with soil type, use level, and amount and type of use.

6.4 The evidence-based method has limitations.

The evidence-based method will not work everywhere. On the Sugar Pine area, for example, some of the soils developed on serpentine were found to be too rocky for the method to work. The gravelly loam soils on the Mendocino NF sites are also close to the limits of gravel content on which the method is usable. The evidence-based method is best suited for areas that have periods of intermittent rainfall, and that have cohesive soils without a high gravel content.

6.5 The method is suitable for use by non-specialists.

During data collection on the pilot studies, OHV managers and recreational staff demonstrated that they could implement the method with minimal training. While some technical support is helpful in setting up the process, once it is implemented, non-specialists should have few problems maintaining it.

6.6 Monitoring is needed to evaluate the effectiveness of the method.

As with any new management method, implementation of the evidence-based method for wet-weather trail management needs to be monitored, particularly during the first few seasons of use. Locating benchmarks, adjusting threshold values, and adjusting triggers for determining when to make observations will all need fine-tuning over time; this should be based on documented measurements and observations.

7.0 References

- Alexander, Earl B., & Poff, R. J. (1985). Soil disturbance and compaction in wildland management: USDA Forest Service, Pacific Southwest Region, Earth Resources Monograph 8.
- Edwards, Richard M. (Ed.). (2011). *Colorado Forest Road Field Handbook*. Fort Collins, CO: Colorado State Forest Service; Colorado State University.
- Furniss, Michael J., Flanagan, Sam A., & McFadin, Bryan A. (2000). Hydrologically-connected roads: An indicator of the influence of roads on chronic sedimentation, surface water hydrology, and exposure to toxic chemicals *Stream Notes, Stream Systems Technology Center*. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station.
- Janicki, Alex J. (1998). Internal Memo to Mi-Wok District Ranger on 98 Polecat Enduro (pp. 2). Sonora, CA: USDA-Forest Service.
- Meyer, Kevin G. (2002). Managing Degraded Off-Highway Vehicle Trails in Wet, Unstable, and Sensitive Environments *0223-2821-MTDC*. Missoula, MT: USDA-Forest Service, Technology and Development Program.
- Mitchell, James K., & Soga, Kenichi. (2005). *Fundamentals of Soil Behavior* (3rd ed.). Hoboken, New Jersey: John Wiley & Sons.
- O'Hare, James P., & Hallock, Brent G. (1980). Soil Survey of the Los Padres National Forest Area, California (pp. 234). USDA-Forest Service, USDA-Soil Conservation Service, University California Agricultural Experiment Station, San Francisco, CA.
- Parker, Troy Scott. (2004). *Natural Surface Trails by Design*. Boulder, CO: Natureshape, LLC.
- Poff, Roger J. (2006). Rolling dips for drainage of OHV trails (pp. 16). Vallejo, CA: USDA-Forest Service, Pacific SW Region.

- Poff, Roger J. (2010). *Soil trafficability and wet weather management of OHV trails*. Paper presented at the International Meeting, Soil Science Society of America, Long Beach, CA.
- Poff, Roger J. (2012). Wet weather management of the Sam Houston Multi-Use trail system: an evidence-based approach (pp. 35). Monrovia, CA: USDA-Forest Service Enterprise Unit *Trails Unlimited*.
- Poff, Roger J., & Groenier, James Scott. (2014). Drain dips for drainage of off-highway vehicle trails (pp. 16). Missoula, MT: USDA-Forest Service, Missoula Technology & Development Center, 1423-2301-MTDC.
- Poff, Roger J., & Ryan, Tom. (2001). A field evaluation of the use of small trail tractors to maintain and construct OHV trails on National Forests in California (pp. 34). Vallejo, CA: USDA-Forest Service, Pacific SW Region.
- Richardson, J. L., Arndt, J. L., & Montgomery, J. A. (2001). Hydrology of wetland and related soils, 35-84. In J. L. Richardson & M. J. Vepraskas (Eds.), *Wetland Soils: Genesis, Hydrology, Landscapes, and Classification* (pp. 417). Boca Raton, Florida: Lewis Publishers.
- U. S. Forest Service. (2011). Soil and Water Conservation Handbook, Chapt. 10 Water Quality Management Handbook *R5 FSH 2509.22* (pp. 237). Vallejo, CA: USDA-Forest Service, Pacific SW Region.
- U. S. Forest Service. (2014). Travel Management Plan Rule. from <http://www.fs.usda.gov/detail/r5/recreation/travelmanagement/?cid=stelprdb5397035>
- USDA-Natural Resources Conservation Service. (2014). Web Soil Survey. from <http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm>

Appendix 1 - Trafficability Assessment

Introduction

Trafficability can be used to predict the risk of damage to OHV trails under wet conditions. This Appendix describes a method for assessing trafficability on native-surface trails using a penetrometer and a moisture meter. The method is based on three variables: soil strength, soil moisture, and observed trail response to traffic. Trafficability is a more direct and reliable method than rainfall for predicting the risk of trail damage.

Soil strength and soil moisture are interdependent: as soil moisture increases, soil strength decreases. This method uses measurements of both soil strength and soil moisture. The measurements of strength are more sensitive at the drier end of the moisture range, while the measurements of moisture are more sensitive at the wetter end of the range, where trail damage occurs.

Soil moisture is measured using a Delta T HH150 moisture meter with the SM150 sensor. Soil strength is measured using a Humboldt H-4120HA C.O.E. Cone Penetrometer. The response to traffic is based on observations of damage to trail treads, using visual indicators of rutting, displacement (puddling), and compaction.

The Process

The Method involves several steps:

- Collecting data on soil strength, soil moisture, and trail condition;
- Developing graphs to correlate soil moisture and soil strength with the risk of trail damage;
- Using the graphs to develop thresholds for opening or closing trails;
- Selecting benchmark sites for monitoring.

Data Collection

Locate several trail segments that include a range of soil moisture conditions. The trail segments should include sections of wet enough so that normal OHV traffic will cause some tread damage. Suitable conditions could occur during the wet season, when trails are closed or would normally be closed.

Allow OHV Traffic to Create Some Damage

After locating suitably wet trail segments, drive an OHV back and forth on the trail to simulate normal riding conditions. Eight to twelve passes are usually sufficient to cause enough tread failure for sampling. The objective is to generate a range of trail conditions, including some sites that have been damaged by traffic, some on the verge of being damaged, and some that have no damage. Alternatively, observations can be made on trails damaged by normal traffic because the trails were open when conditions were too wet.

Locate Sample Points Along the Trail

Walk the trail and locate sample sites in the five condition classes shown in Table 1. Make observations and measurements on at least 12 sample points, including at least two of each of

the five condition classes. A total of 25 to 30 sample points is ideal. Repeat the process for each major soil type in the trail system.

Measurements and Observations

Collect data in the trail tread and/or in drainage structures as shown in Figure 1:

- At the drain dip outlet (D1);
- On the shoulder of the drain dip on the outlet side (D2)

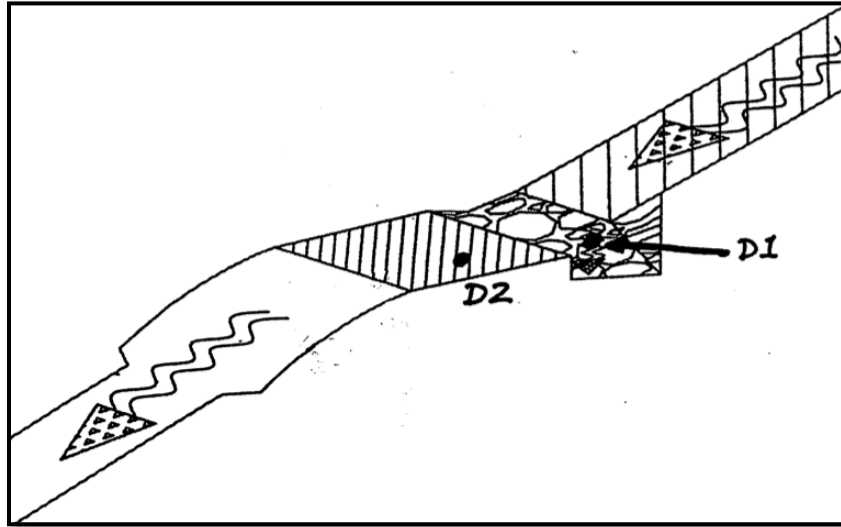


Figure 1. Sampling Sites

Measure strength and moisture as close as possible to the vehicle tracks where the trail condition is observed. Take measurements in the one-third of the trail that is on the drain dip outlet side.

Soil Moisture

Remove the center pin from the 4-pin insertion tool and use the tool to create three holes for inserting the electrodes. Insert the SM150 electrodes into two of the holes and take a reading. After the first reading remove the sensor and rotate it to use the next set of holes. Repeat to get three readings for each sample site. The HH150 reads percent volumetric moisture directly.

Soil Strength

Measure soil strength with the penetrometer. Take three readings at each of the sample points. Record soil strength as pounds per square inch (psi) or cone index (ci).

Tread Condition

Observe vehicle tracks at each sample points. Record tread condition as: *Very Poor* (5), *Poor* (4), *Marginal* (3), *Good* (2), or *Very Good* (1).

Aids to determining condition classes are shown in Figure 2, in Table 1, and in photos and sketches at the end of this report. *Very Poor* condition is indicated by rutting, with rut volume the same as berm volume (puddling); *Poor* condition is indicated by shallow ruts with slight berms

(both puddling and compaction); *Marginal* is indicated by shallow ruts or tracks with no berms (compaction); *Good* is indicated by visible tracks or tire cleats marks (slight compaction); *Very Good* is indicated by no visible tracks or cleat marks (no compaction).

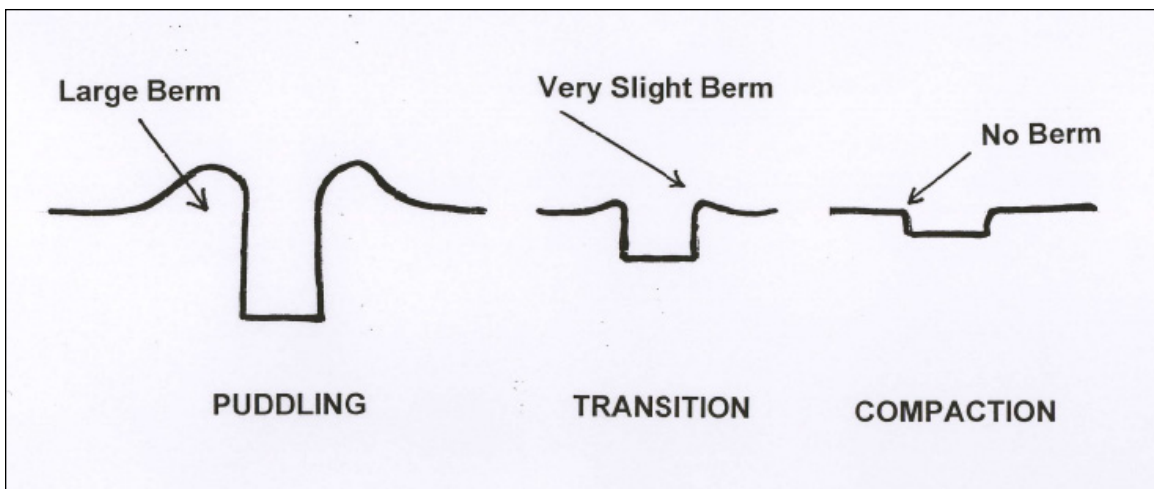


Figure 2. Visual Indicators of Compaction and Puddling

	Condition	Risk Level	Visual Indicator	Deformation
5	Very Poor	Very High	Ruts with berm volume same as rut	Puddling
4	Poor	High	Shallow rut with slight berm	Puddling, Compaction
3	Marginal	Threshold	Shallow track or rut with no berm	Compaction
2	Good	Low	Tire cleat marks or shallow tracks	Slight Compaction
1	Very Good	Very Low	No visible tracks or cleat marks	None

Table 1. Condition Classes, Risk Levels, Visual Indicators, and Deformation

Measurement Depth

Take measurements at a 0 to 2-inch depth for wetting front conditions and at a 2 to 4-inch depth for drying front conditions.

Create Thresholds for Risk of Tread Damage

For each soil type sampled, enter the data in a spreadsheet and plot the data points on a scatter diagram (Figure 4 is an example). *Increasing* soil strength is plotted on the y-axis as pound-force per square inch (psi); *decreasing* soil moisture is plotted on the x-axis as percent moisture (%). Use different symbols (triangle, circle, square, etc.) and/or colors to show the condition class for each data point as very high, high, moderate, low, and very low risk of trail damage.

After the data have been plotted on the scatter diagram, draw a horizontal line through the cluster of points rated moderate to determine the *soil strength threshold* and draw a vertical line through the cluster to determine the *soil moisture threshold*. This visual method may be supplemented by calculating averages for the data points in moderate condition.

In the example shown in Figure 3, the strength threshold is 135 psi, and the moisture threshold is 28 percent. This means, for this soil and depth, the risk of tread failure is high when the soil strength is less than 135 psi, or when the soil moisture is greater than 28 percent by volume.

After the threshold values for each soil have been developed, the threshold values can be used to predict when trails can be opened with a low risk of damage, or when they should be closed to avoid damage.

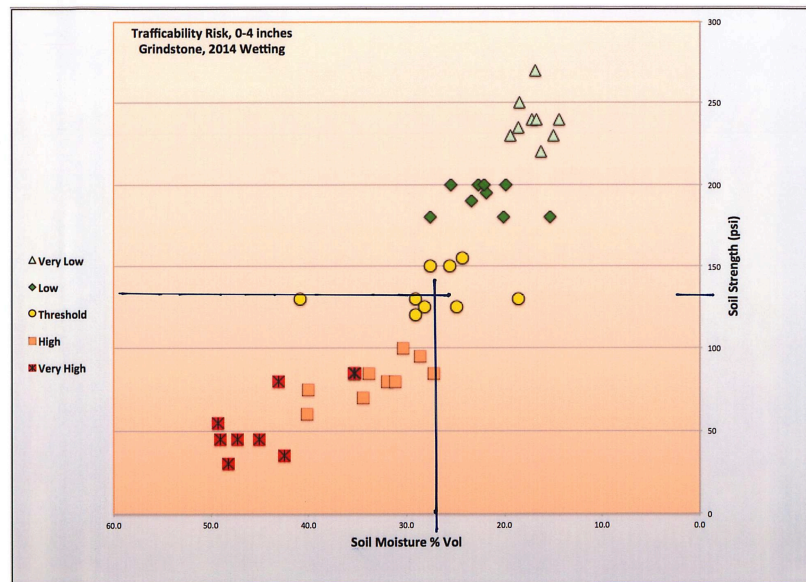


Figure 4. Scatter Diagram with Thresholds

Locate Benchmark Sites

An important step in the process is locating representative or benchmark sites to monitor. Benchmark sites should be representative of the whole trail system, and should also be readily accessible. Because conditions within a trail system vary from place to place, selecting benchmark sites is a critical step in the process.

Using the HH150 Moisture Meter with SM150 Moisture Sensor

The HH150 Moisture Meter with the SM150 Moisture Sensor is very simple to set up and use, and provides quick and highly accurate moisture readings. However, some care is required in its use, particularly to avoiding damaging the electrodes. Photos of the HH150 are attached.

Set Up

Insert the batteries. Use only good quality *alkaline* batteries. Remove the batteries when the meter will not be in use for an extended time period. Connect the SM150 sensor to the HH150 meter. Carefully align the connectors before pushing the parts together. Screw together firmly.

With the meter OFF, press the *right off-menu* button. This wakes the meter and allows you to set the display readings. Set to *% volumetric water content* and to *mineral soil*. Then press **off** to save the current setting and turn the meter off. This is a one-time step unless the batteries are removed. If set up correctly, the moisture readout will show “mineral” and “% vol.”

Taking Readings

Prepare the sample site by lightly scraping the top 1/8- to 1/4-inch of soil to create a flat surface. Use the 4-pin insertion tool (with the center pin removed) to create a set of three holes for the probe electrodes.

Push the SM150 rods into the soil until the rods are fully inserted and have good soil contact. There should be no air space between the soil and the base of the sensor. Insert the rods slowly. If you feel resistance you have probably hit a stone or pebble. Stop and re-insert at a new location. Avoid pressure that will change the rod alignment. If the site is too dry and hard to insert the rods, the site is well under the moisture threshold, anyhow. Just document the condition with a penetrometer reading.

With the meter OFF, press the *left on-read* button to take a reading. The reading will be instantaneous. The meter will sleep automatically after about 30 seconds.

Care and Safety

- The sensor rods of the SM150 are very sharp to ease insertion. They can puncture skin, so care is advised.
- Do not touch the sensor rods or expose them to other sources of static charge, particularly when powered up or attached to the cable. An electrostatic discharge from your body can typically cause a temporary -10mV offset in sensor readings for up to one hour. At worst, it could even permanently damage the sensor.
- Do not pull the SM150 out of the soil by its cable.

Using the Humboldt H-4120HA C.O.E. Cone Penetrometer

Penetrometer Adjustments and Maintenance

As with any fine instrument, the cone penetrometer should require little maintenance or adjustment if treated carefully. Before using the penetrometer, check to see that the rod and cone tip are not loose, and that the handle is tight, especially if the penetrometer has been disassembled for transport. The handle is tightened with a set screw (wrench provided).

Taking Soil Strength Measurements

Loosen the dial lock knob and, while holding the penetrometer vertically in the air by the T-handle, set the dial to zero. Resetting the dial to zero may need to be done frequently to compensate for the effects of temperature changes on the proving ring.

Push the penetrometer into the soil slowly and steadily, keeping the pressure on the handle as constant as possible. Over time, and with practice, consistent readings should be easy to achieve. To estimate the depth of penetration, the first six inches of the rod are marked with 1-inch wide knurled sections.

The dial on the penetrometer reads directly in pounds per square inch (psi). When using a ½ inch 30-degree cone tip, it also reads cone index (ci) directly.

There are many models and styles of penetrometers. Other types will have slightly different operating instructions. For consistency, use a penetrometer with a ½ inch 30-degree cone tip that measures psi or ci.



Figure 4. C.O.E. Penetrometer

Consistency

Consistency is important when making measurements and observations. A qualified professional should initially train persons making the measurements and observations. Training should include principles of soil behavior as it relates to OHV traffic; operation and maintenance of the moisture meter; use of the 4-pin insertion tool; operation and maintenance of the penetrometer; and visual indicators of tread failure.

Other Applications

When developing threshold values to predict the risk of damage for an Enduro event, many vehicle passes are needed to simulate the pumping effect. When making measurements for Enduro events, measurements should be taken on treads as well as on drain dips. Measurements for an Enduro should be taken at a variety of depths to determine which depth is the best predictor of risk, but at least to 4 to 6 inches. Thresholds will vary with the type of vehicles, the amount of traffic, and whether the site is in a wetting or drying front, so some experimentation is needed.



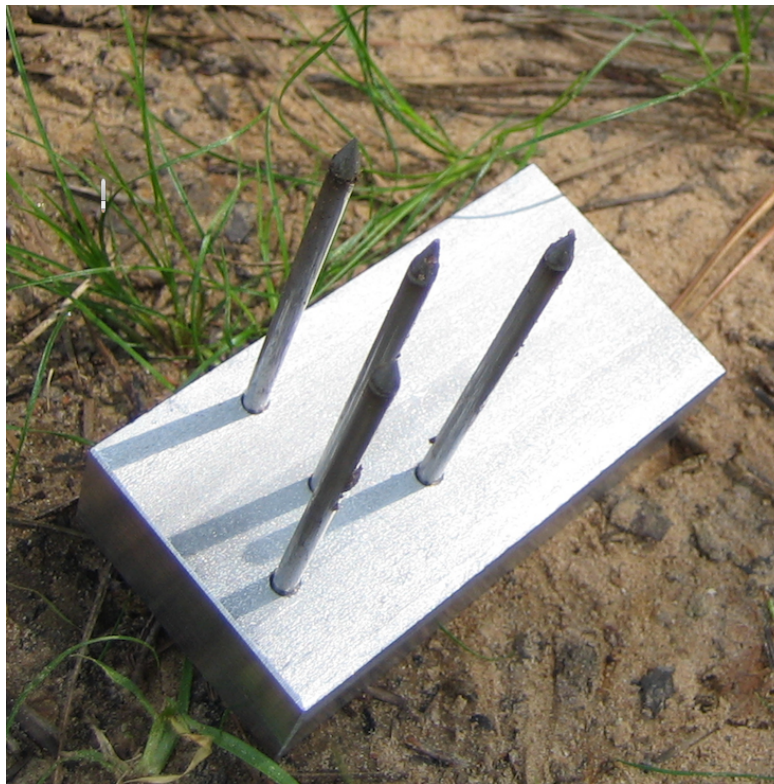
Delta T HH150 Kit



Insertion of Delta T SM150 Moisture Sensor



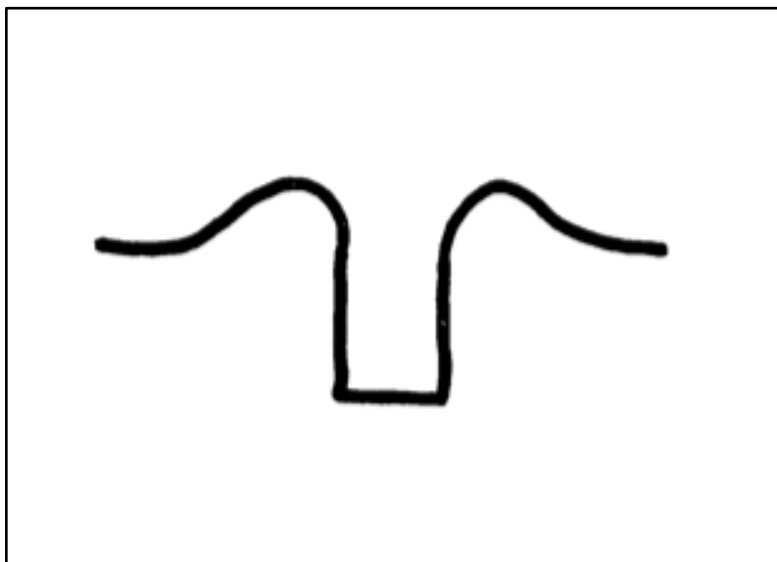
Taking Moisture Reading on Delta T HH150 Moisture Meter



4-Pin Insertion Tool



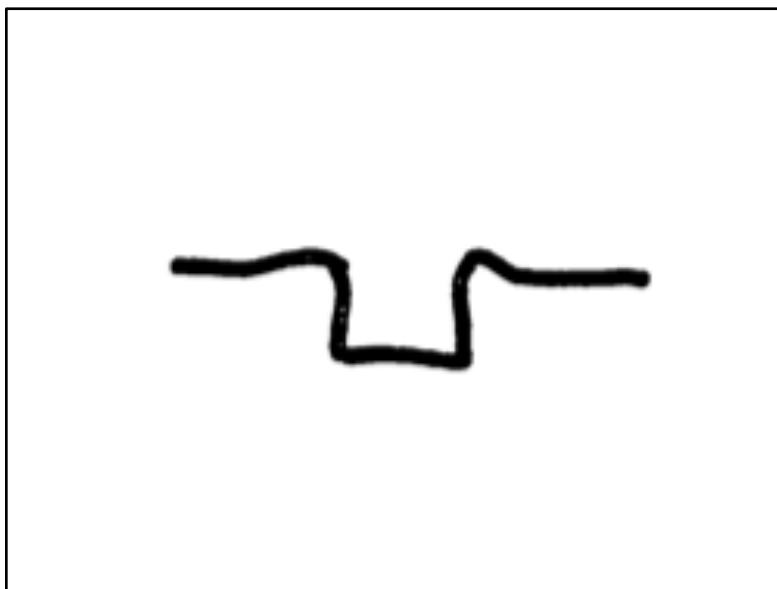
Class 5 Condition



Class 5 Rut Crossection



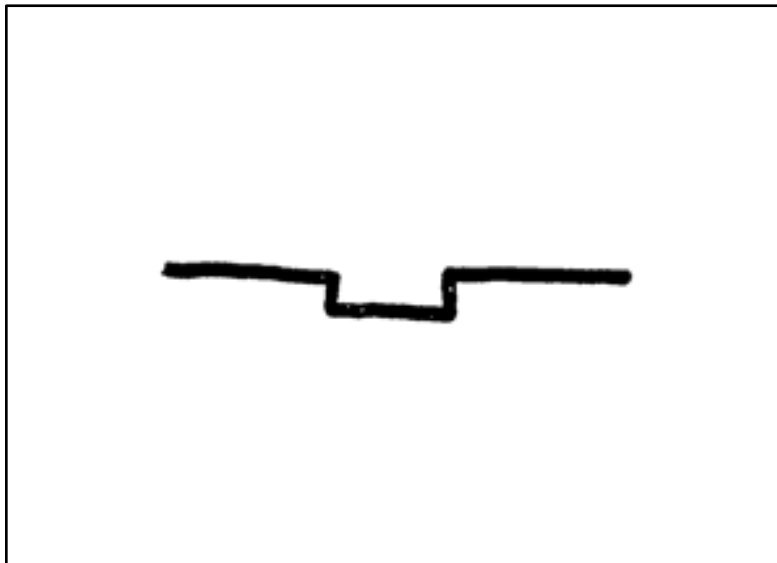
Class 4 Condition



Class 4 Rut Crossection



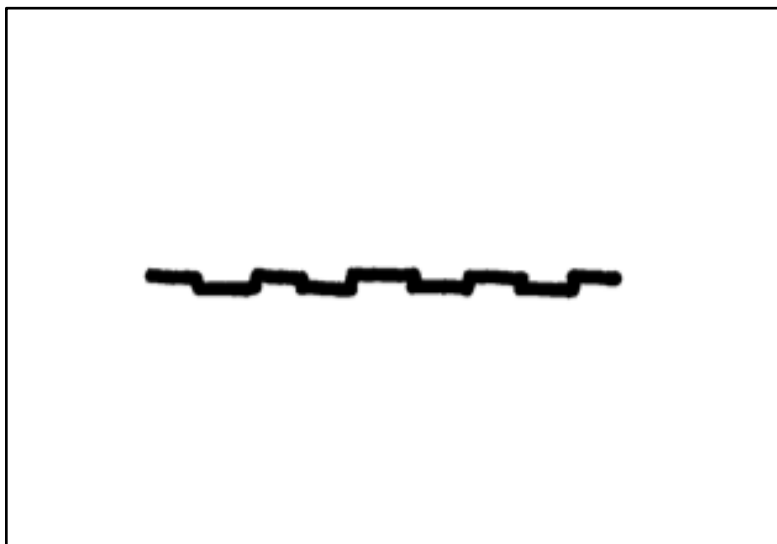
Class 3 Condition



Class 3 Rut Crossection



Class 2 Condition



Class 2 Crossection



Class 1 Condition



Class 1 Crossection

An Evidence-based Process for Wet-weather Closures on the Pozo Area, Santa Lucia RD, Los Padres NF

Introduction

This report is on one of four pilot studies conducted to test the effectiveness of evidence-based wet-weather closures on National Forests in California. The studies were funded by a grant from the CA OHV Commission. The objective of the grant was to examine existing criteria for wet-weather OHV trail closures, and propose alternative strategies for managing OHV trails under wet-weather conditions. The evidence-based process in this report can be used as an alternative to a seasonal closure or to a precipitation-based closure.

The process described in this report is based on a correlation of observed damage to OHV trails with measurements of soil moisture and soil strength. The threshold values for soil moisture and strength used in this report are based on actual data collected on Pozo area trails.

This report contains specific instructions on how to use measurements of soil moisture and soil strength to determine when to open or close trails. It is a set of implementation instructions. This report does not explain how the threshold values for the Pozo area were developed. That information, and more detailed information on wet-weather management of OHV trails, is provided in *Wet-weather Management of OHV Trails on National Forests in California (2014)*, of which this report is an Appendix.

The Process

The process includes six elements:

1. *Threshold values* are measurements of soil strength and soil moisture that are used to determine the risk of trail damage. When threshold values are exceeded, the risk of damage to trails is moderate to high.
2. *Benchmark sites* are sampling locations where measurements are made to determine whether or not threshold values are exceeded. Benchmark sites are selected to represent conditions across a whole trail system or a portion of it.
3. *Protocols for measurement and analysis* are specific instructions on how the measurements of soil strength and moisture are taken, and define how these measurements are interpreted to determine whether or not the threshold is exceeded.
4. *Decision tree* is a flowchart that specifies when benchmark sites are to be monitored and when to open or close trails.
5. *Documentation* A standardized form is used to document field measurements, calculations, and decisions to open or close trails. Completed forms can also be used as part of an implementation and effectiveness monitoring program.
6. *Forest Order* A legal document signed by the Forest Supervisor that specifies the conditions under which trails will be opened or closed and penalties for violations of the closure.

Threshold Values

Threshold values of soil moisture and soil strength for the Pozo area are shown in Table 1. The thresholds are based on measurements and observations that were made on Pozo trails and

are unique to the Pozo area. When these threshold values are exceeded, there is a moderate to high risk that OHV traffic will cause damage to trail drainage structures and trail treads.

Measurement Type	Threshold
Soil Moisture Content (% by volume)	> 25.0
Soil Strength (psi)	< 145

Table 1. Threshold Values of Soil Moisture and Soil Strength for Pozo Trails¹

Benchmark Sites

Five benchmark sites have been selected to represent trail conditions on the Pozo trail system. The map on page 7 of this report shows the locations of the benchmark sites.

Measurement Protocols

Sampling Locations

At each benchmark site, twelve (12) measurements of soil strength and moisture are taken. The measurements are made at two sites on a drain dip structure: one set of measurements in the drain dip outlet (D1 in Figure 1), and one set on the first shoulder (D2 in Figure 1) of the dip structure. Each set includes three (3) measurements of soil moisture content, and three (3) measurements of soil strength. All measurements are taken within the third of the trail tread on the drain dip outlet side of the trail, and all measurements are made in the 0 to 2-inch surface layer of the tread.

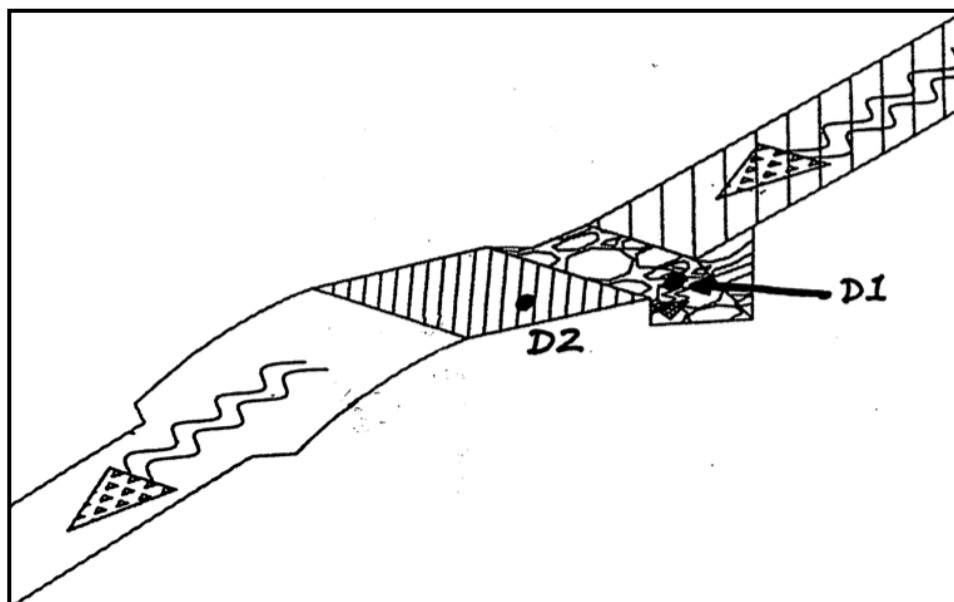


Figure 1. Drain Dip Showing Sample Locations

¹ Measurements above the threshold for moisture content, or below the threshold for soil strength, are defined as exceeding the threshold, and predict a moderate to high risk of damage to drainage structures and trail treads under OHV traffic.

Soil Moisture

Soil moisture is measured using the HH150 moisture meter fitted with the SM150 sensor. At sample site D1, prepare the surface by lightly scraping the top 1/8- to 1/4-inch of soil to create a flat surface. Use the insertion kit to create three sets of holes for the probe sensors. Insert the sensor until it is completely flush with the soil surface and then measure and record the soil moisture content. Repeat for sample site D2. The form should now have two sets of three moisture measurements.

If the soil is too hard and compacted to insert the moisture probe without the risk of damage to the electrodes, the soil moisture is probably well within the threshold. In this case, only measure soil strength with the penetrometer as described in the next section. Note on the form why moisture was not measured.

Soil Strength

After measuring soil moisture, return to the same two sites (D1 and D2) and measure soil strength using the penetrometer. Make the measurements at the same points where the moisture was measured, or as close as practical.

Insert the penetrometer with a steady and even pressure. If stones or roots are encountered, take additional measurements to get a consistent set of three readings for each site (D1 and D2). The form should now have four sets of three measurements; two sets for moisture and two sets for strength.

Threshold Determination

Thresholds for Individual Benchmark Sites

Averages of the measurements taken at D1 and D2 are used to determine whether or not each benchmark exceeds the threshold. Average each of the four sets of measurements and record this average on the form. Mark (circle yes or no) whether or not the average for each set exceeds the threshold.

Use the number of data sets over threshold to determine whether or not the benchmark site exceeds the threshold. If two or more of the four data sets exceed the threshold, the benchmark site exceeds the threshold. Mark this on the form.

Threshold for the Trail System

At the bottom of the form, note how many benchmark sites exceed the threshold. If the threshold is exceeded at *two or more* of the five benchmark sites, the trail system shall be closed or shall remain closed. If only one of the five benchmarks exceeds the threshold, the trail system shall be opened or shall remain open to use.

Where the measurements are very close to the threshold values, it may be appropriate to recommend opening or closing the trail system based on observed soil conditions, even though the threshold criteria have not been met. Record the observations and reasons for such a recommendation at the bottom of the form.

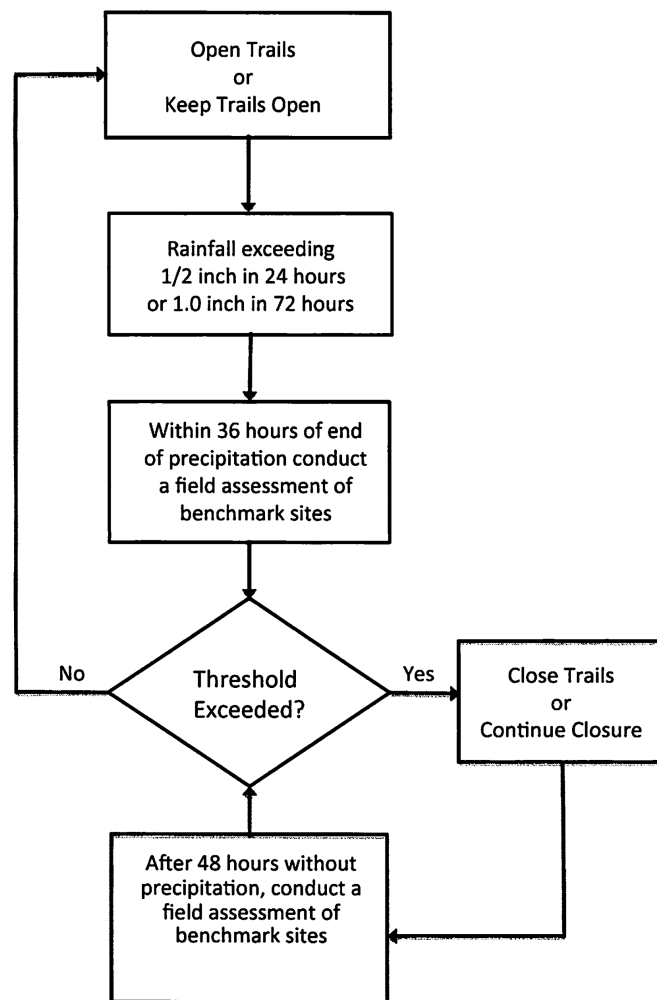
Decision Tree

The flowchart in Figure 2 shows when measurements of soil strength and moisture shall be taken, and how the threshold values at the benchmark sites affect decisions to open and close trails.

Monitoring

Review the completed forms annually to monitor the implementation and effectiveness of the closure policy.

Figure 2. Decision Tree for Pozo Area Trails



Additional Instructions for Measuring Soil Moisture and Strength

HH150 Moisture Meter with SM150 Moisture Sensor

The HH150 Moisture Meter with SM150 Moisture Sensor is simple to set up and use, and provides quick and highly accurate moisture readings. However, some care is required in its use, especially to avoid damaging the sensor rods.

Set Up

Insert the batteries. Use only good quality alkaline batteries. Remove the batteries when the meter will not be in use for an extended time period. Connect the SM150 sensor to the HH150 meter. Align connectors carefully before pushing the parts together. Screw together firmly.

With the meter OFF, press the right off-menu button. This wakes the meter and allows you to set the display readings. Set to % volumetric water content and to mineral soil. Then press **off** to save the current setting and turn the meter off. This is a one-time step unless the batteries are removed. If set up correctly, the moisture readout will show “mineral” and “% vol.”

Taking Readings

Clear away any stones and scrape the surface to create a flat surface to allow the sensor to make a full contact with the soil.

Remove the center pin from the 4-pin insertion tool and use the tool to create 3 holes in the soil. If the soil is firm, gently tap the block and pins with a hammer to create the holes. Remove the insertion pin tool carefully to avoid displacing or fracturing the soil.

Gently insert the SM150 rods into two of the holes punched by the insertion tool. The sensor rods must be fully inserted. Make sure the base of the sensor makes a good contact with the soil surface. Insert the rods slowly. If resistance is felt, it is probably a stone or pebble. Try a different set of two holes, or move to a new location. Avoid any pressure that will change the rod alignment.

With the meter OFF, press the left on-read button to take a reading. The reading will be instantaneous. The meter will sleep after about 30 seconds.

Care and Safety

- The pins used in the 4-pin insertion tool are extremely sharp and dangerous. Take care to keep track of its location so you do not accidentally step on it or place your hand on it. When not in use, place it on its side or with the pins partly in the soil to lessen the risk of punctures. Bright yellow tape—or bright paint—around the edge of the pin block will make the tool more visible in the field.
- The sensor rods of the SM150 are sharp to ease insertion. They can puncture skin, so care is advised.
- Do not touch the sensor rods or expose them to other sources of *static charge*, particularly when powered up or attached to the cable. An electrostatic discharge from your body can typically cause a temporary -10mV offset in sensor readings for up to one hour. At worst, it could even permanently damage the sensor.
- Do not pull the SM150 out of the soil by its cable.

Humboldt H-4120HA C.O.E. Cone Penetrometer

Penetrometer Adjustments and Maintenance

If treated carefully, as with any fine instrument, the cone penetrometer should require little maintenance or adjustment. Before using the penetrometer, check to see that the rod and cone tip are not loose, and that the handle is tight, especially if the penetrometer has been disassembled for transport. The handle is tightened with a set screw (wrench provided).

Taking Soil Strength Measurements

Loosen the dial lock knob and, while holding the penetrometer vertically in the air by the T-handle, set the dial to zero. Resetting the dial to zero may need to be done frequently to compensate for the effects of temperature changes on the proving ring.

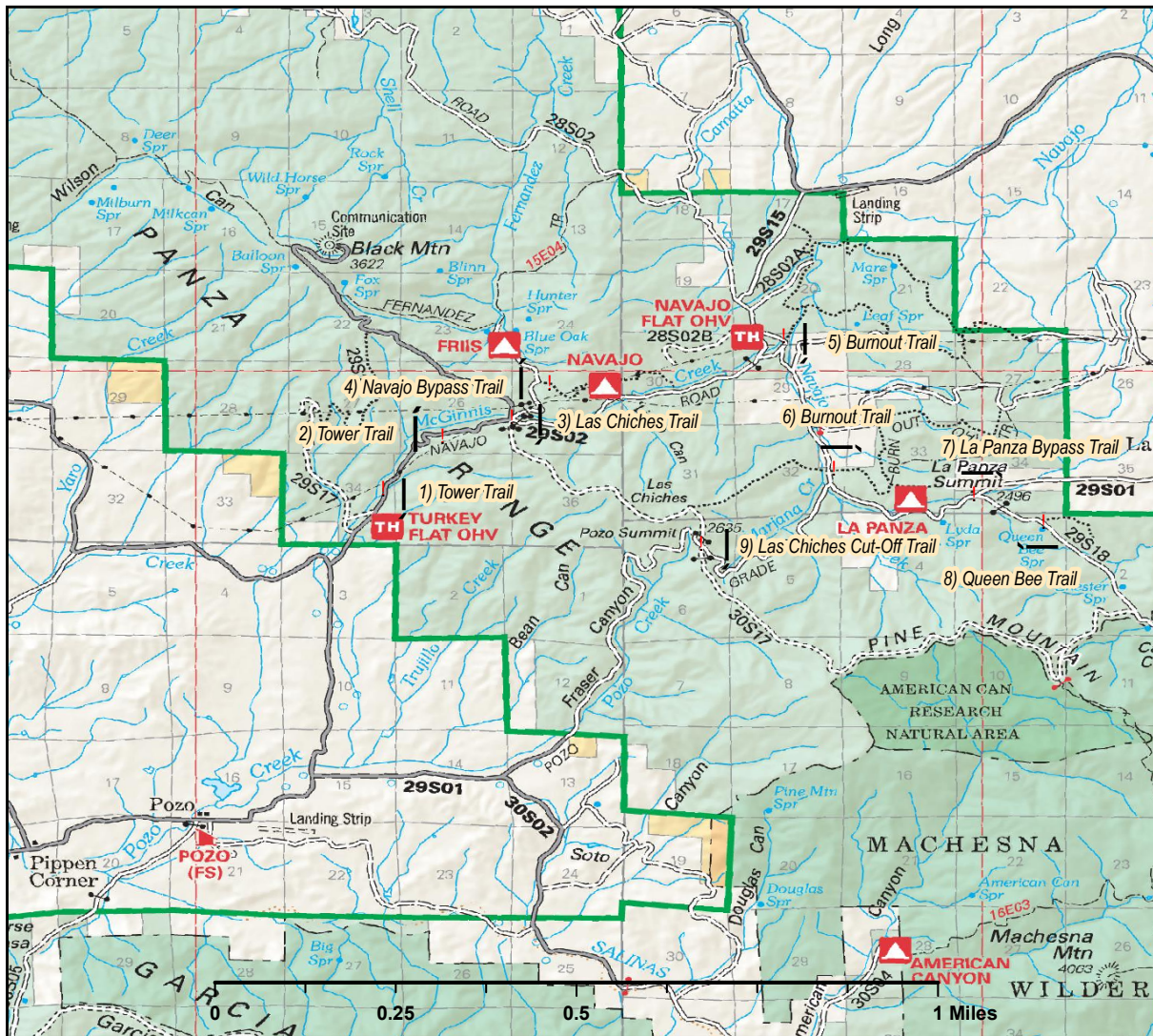
Push the penetrometer into the soil slowly and steadily, keeping the pressure on the handle as even as possible. Over time, and with practice, consistent readings should be easy to achieve. To estimate the depth of penetration, the first six inches of the rod are marked with 1-inch wide knurled sections.

The dial on the penetrometer reads directly in pound-force per square inch (psi). When using a ½ inch 30-degree cone tip, it also reads cone index (ci) directly.

There are many models and styles of penetrometers. Other types will have slightly different operating instructions. For consistency, use a penetrometer with a ½ inch 30-degree cone tip that measures psi or ci.

Consistency

Consistency is important when making measurements and observations. A qualified professional should initially train persons making the measurements and observations. Training should include principles of soil behavior as it relates to OHV traffic; operation and maintenance of the moisture meter; use of the 4-pin insertion tool; operation and maintenance of the penetrometer; and visual indicators of tread failure.



Pozo Trails Soil Mountoring Sample Points.

- 1) Tower Trail # 16E24
- 2) Tower Trail # 16E24
- 3) Las Chiches Trail # 16E08
- 4) Navajo Bypass Trail # 16E23
- 5) Burnout Trail # 16E21
- 6) Burnout Trail # 16E21
- 7) La Panza Bypass Trail # 18E05
- 8) Queen Bee Trail # 16E04
- 9) Las Chiches Cut-Off Trail # 16E02

Legend

! Soil_Sample_Points

Documentation of Field Assessment for Pozo Area Trail Closure/Opening

Trail System		Date		By	
Most Recent Rainfall		Drying Conditions			
Benchmark – Site	Moisture		Strength		
	Outlet (D1)	Shoulder (D2)	Outlet (D1)	Shoulder (D2)	
1-1					
1-2					
1-3					
Average					
Site Exceeds Threshold	Yes / No	Yes / No	Yes / No	Yes / No	
Benchmark Exceeds Threshold	Yes / No				
2-1					
2-2					
2-3					
Average					
Site Exceeds Threshold	Yes / No	Yes / No	Yes / No	Yes / No	
Benchmark Exceeds Threshold	Yes / No				
3-1					
3-2					
3-3					
Average					
Site Exceeds Threshold	Yes / No	Yes / No	Yes / No	Yes / No	
Benchmark Exceeds Threshold	Yes / No				
4-1					
4-2					
4-3					
Average					
Site Exceeds Threshold	Yes / No	Yes / No	Yes / No	Yes / No	
Benchmark Exceeds Threshold	Yes / No				
5-1					
5-2					
5-3					
Average					
Site Exceeds Threshold	Yes / No	Yes / No	Yes / No	Yes / No	
Benchmark Exceeds Threshold	Yes / No				
Notes on Trail Conditions:					
Decision: Open / Close			Approval		

An Evidence-based Process for Wet-weather Closures on the Stonyford Area, Mendocino National Forest

Introduction

This report is on one of four pilot studies conducted to test the effectiveness of evidence-based wet-weather closures on National Forests in California. The studies were funded by a grant from the CA OHV Commission. The objective of the grant was to examine existing criteria for wet-weather OHV trail closures, and propose alternative strategies for managing OHV trails under wet-weather conditions. The evidence-based process in this report can be used as an alternative to a seasonal closure or to a precipitation-based closure.

The process described in this report is based on a correlation of observed damage to OHV trails with measurements of soil moisture and soil strength. The threshold values for soil moisture and strength used in this report are based on actual data collected on Stonyford area trails.

This report contains specific instructions on how to use measurements of soil moisture and soil strength to determine when to open or close trails. It is a set of implementation instructions. This report does not explain how the threshold values for the Stonyford area were developed. That information, and more detailed information on wet-weather management of OHV trails, is provided in *Wet-weather Management of OHV Trails on National Forests in California (2014)*, of which this report is an Appendix.

The Process

The process includes six elements:

1. *Threshold values* are measurements of soil strength and soil moisture that are used to determine the risk of trail damage. When threshold values are exceeded, the risk of damage to trails is moderate to high.
2. *Benchmark sites* are sampling locations where measurements are made to determine whether or not threshold values are exceeded. Benchmark sites are selected to represent conditions across a whole trail system or a portion of it.
3. *Protocols for measurement and analysis* are specific instructions on how the measurements of soil strength and moisture are taken, and define how these measurements are interpreted to determine whether or not the threshold is exceeded.
4. *Decision tree* is a flowchart that specifies when benchmark sites are to be monitored and when to open or close trails.
5. *Documentation* A standardized form is used to document field measurements, calculations, and decisions to open or close trails. Completed forms can also be used as part of an implementation and effectiveness monitoring program.
6. *Forest Order* A legal document signed by the Forest Supervisor that specifies the conditions under which trails will be opened or closed and penalties for violations of the closure.

Threshold Values

Threshold values of soil moisture and soil strength for the Stonyford area are shown in Table 1. The thresholds are based on measurements and observations that were made on Stonyford area trails and are unique to the Stonyford area. When these threshold values are exceeded,

there is a moderate to high risk that OHV traffic will cause damage to trail drainage structures and trail treads.

Measurement Type	Threshold
Soil Moisture Content (% by volume)	> 28.0
Soil Strength (psi)	< 135

Table 1. Threshold Values of Soil Moisture and Soil Strength for Stonyford Area Trails¹

Benchmark Sites

Five benchmark sites have been selected to represent trail conditions on the Stonyford area trail system. The map on page 7 of this report shows the locations of the benchmark sites.

Measurement Protocols

Sampling Locations

At each benchmark site, twelve (12) measurements of soil strength and moisture are taken. The measurements are made at two sites on a drain dip structure: one set of measurements in the drain dip outlet (D1 in Figure 1), and one set on the first shoulder (D2 in Figure 1) of the dip structure. Each set includes three (3) measurements of soil moisture content, and three (3) measurements of soil strength. All measurements are taken within the third of the trail tread on the drain dip outlet side of the trail, and all measurements are made in the 0 to 2-inch surface layer of the tread.

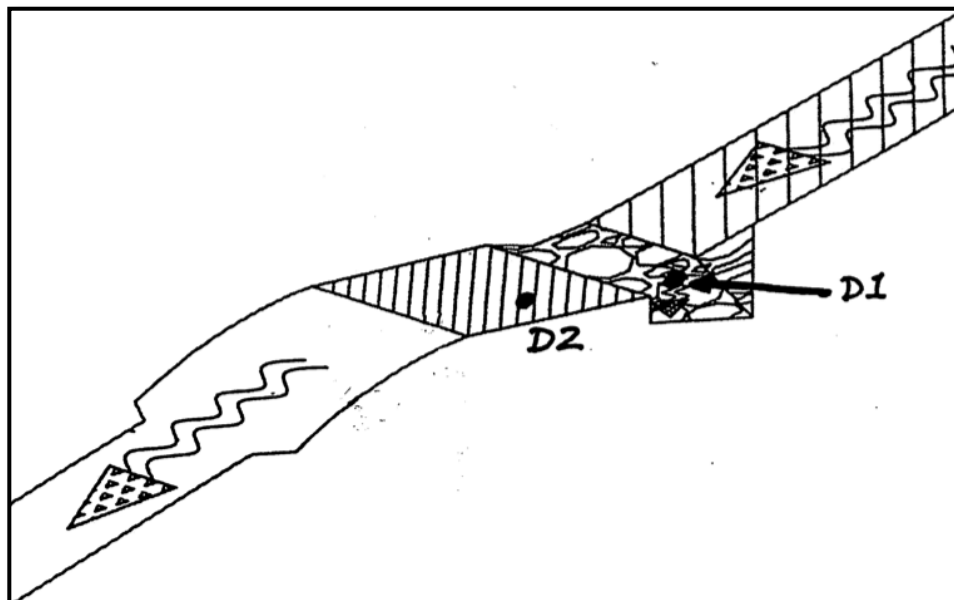


Figure 1. Drain Dip Showing Sample Locations

¹ Measurements above the threshold for moisture content, or below the threshold for soil strength, are defined as exceeding the threshold, and predict a moderate to high risk of damage to drainage structures and trail treads under OHV traffic.

Soil Moisture

Soil moisture is measured using the HH150 moisture meter fitted with the SM150 sensor. At sample site D1, prepare the surface by lightly scraping the top 1/8- to 1/4-inch of soil to create a flat surface. Use the insertion kit to create three sets of holes for the probe sensors. Insert the sensor until it is completely flush with the soil surface and then measure and record the soil moisture content. Repeat for sample site D2. The form should now have two sets of three moisture measurements.

If the soil is too hard and compacted to insert the moisture probe without the risk of damage to the electrodes, the soil moisture is probably well within the threshold. In this case, only measure soil strength with the penetrometer as described in the next section. Note on the form why moisture was not measured.

Soil Strength

After measuring soil moisture, return to the same two sites (D1 and D2) and measure soil strength using the penetrometer. Make the measurements at the same points where the moisture was measured, or as close as practical.

Insert the penetrometer with a steady and even pressure. If stones or roots are encountered, take additional measurements to get a consistent set of three readings for each site (D1 and D2). The form should now have four sets of three measurements; two sets for moisture and two sets for strength.

Threshold Determination

Thresholds for Individual Benchmark Sites

Averages of the measurements taken at D1 and D2 are used to determine whether or not each benchmark exceeds the threshold. Average each of the four sets of measurements and record this average on the form. Mark (circle yes or no) whether or not the average for each set exceeds the threshold.

Threshold for the Trail System

At the bottom of the form, note how many benchmark sites exceed the threshold. If the threshold is exceeded at one or more of the three benchmark sites, the trail system shall be closed or shall remain closed.

Where the measurements are very close to the threshold values, it may be appropriate to recommend opening or closing the trail system based on observed soil conditions, even though the threshold criteria have not been met. Record the observations and reasons for such a recommendation at the bottom of the form.

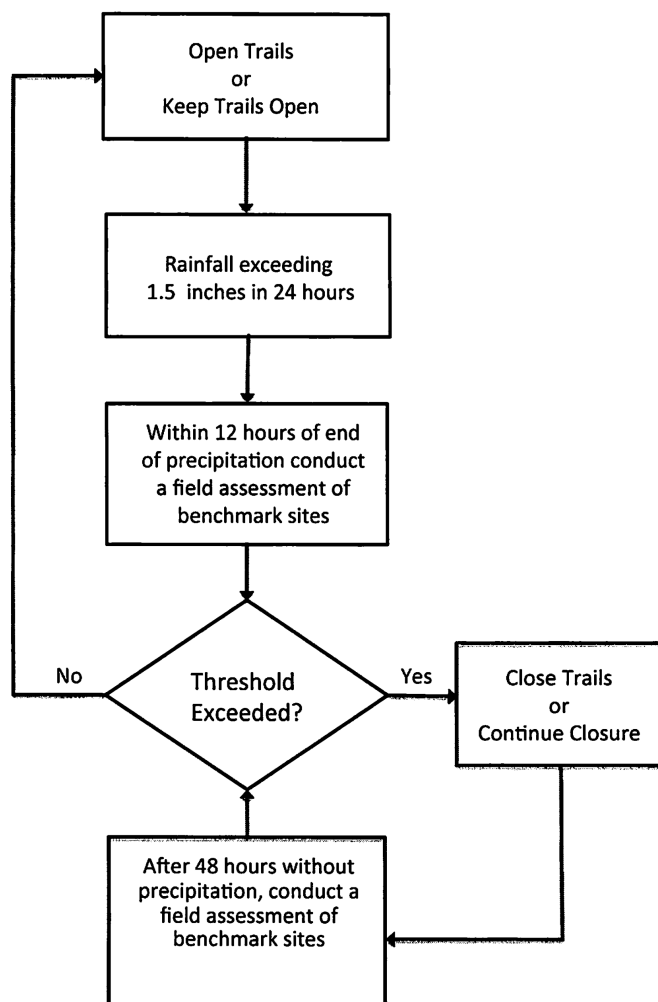
Decision Tree

The flowchart in Figure 2 shows when measurements of soil strength and moisture shall be taken, and how the threshold values at the benchmark sites affect decisions to open and close trails.

Monitoring

Review the completed forms annually to monitor the implementation and effectiveness of the closure policy.

Figure 2. Stonyford Trail Closures



Additional Instructions for Measuring Soil Moisture and Strength

HH150 Moisture Meter with SM150 Moisture Sensor

The HH150 Moisture Meter with SM150 Moisture Sensor is simple to set up and use, and provides quick and highly accurate moisture readings. However, some care is required in its use, especially to avoid damaging the sensor rods.

Set Up

Insert the batteries. Use only good quality *alkaline* batteries. Remove the batteries when the meter will not be in use for an extended time period. Connect the SM150 sensor to the HH150 meter. Align connectors carefully before pushing the parts together. Screw together firmly.

With the meter OFF, press the *right off-menu* button. This wakes the meter and allows you to set the display readings. Set to *% volumetric water content* and to *mineral soil*. Then press **off** to save the current setting and turn the meter off. This is a one-time step unless the batteries are removed. If set up correctly, the moisture readout will show “mineral” and “% vol.”

Taking Readings

Clear away any stones and scrape the surface to create a flat surface to allow the sensor to make a full contact with the soil.

Remove the center pin from the 4-pin insertion tool and use the tool to create 3 holes in the soil. If the soil is firm, gently tap the block and pins with a hammer to create the holes. Remove the insertion pin tool carefully to avoid displacing or fracturing the soil.

Gently insert the SM150 rods into two of the holes punched by the insertion tool. The sensor rods must be fully inserted. Make sure the base of the sensor makes a good contact with the soil surface. Insert the rods slowly. If resistance is felt, it is probably a stone or pebble. Try a different set of two holes, or move to a new location. Avoid any pressure that will change the rod alignment.

With the meter OFF, press the *left on-read* button to take a reading. The reading will be instantaneous. The meter will sleep after about 30 seconds.

Care and Safety

- The pins used in the 4-pin insertion tool are extremely sharp and dangerous. Take care to keep track of its location so you do not accidentally step on it or place your hand on it. When not in use, place it on its side or with the pins partly in the soil to lessen the risk of punctures. Bright yellow tape—or bright paint—around the edge of the pin block will make the tool more visible in the field.
- The sensor rods of the SM150 are sharp to ease insertion. They can puncture skin, so care is advised.
- Do not touch the sensor rods or expose them to other sources of *static charge*, particularly when powered up or attached to the cable. An electrostatic discharge from your body can typically cause a temporary -10mV offset in sensor readings for up to one hour. At worst, it could even permanently damage the sensor.
- Do not pull the SM150 out of the soil by its cable.

Humboldt H-4120HA C.O.E. Cone Penetrometer

Penetrometer Adjustments and Maintenance

If treated carefully, as with any fine instrument, the cone penetrometer should require little maintenance or adjustment. Before using the penetrometer, check to see that the rod and cone tip are not loose, and that the handle is tight, especially if the penetrometer has been disassembled for transport. The handle is tightened with a set screw (wrench provided).

Taking Soil Strength Measurements

Loosen the dial lock knob and, while holding the penetrometer vertically in the air by the T-handle, set the dial to zero. Resetting the dial to zero may need to be done frequently to compensate for the effects of temperature changes on the proving ring.

Push the penetrometer into the soil slowly and steadily, keeping the pressure on the handle as even as possible. Over time, and with practice, consistent readings should be easy to achieve. To estimate the depth of penetration, the first six inches of the rod are marked with 1-inch wide knurled sections.

The dial on the penetrometer reads directly in pound-force per square inch (psi). When using a ½ inch 30-degree cone tip, it also reads cone index (ci) directly.

There are many models and styles of penetrometers. Other types will have slightly different operating instructions. For consistency, use a penetrometer with a ½ inch 30-degree cone tip that measures psi or ci.

Consistency

Consistency is important when making measurements and observations. A qualified professional should initially train persons making the measurements and observations. Training should include principles of soil behavior as it relates to OHV traffic; operation and maintenance of the moisture meter; use of the 4-pin insertion tool; operation and maintenance of the penetrometer; and visual indicators of tread failure.

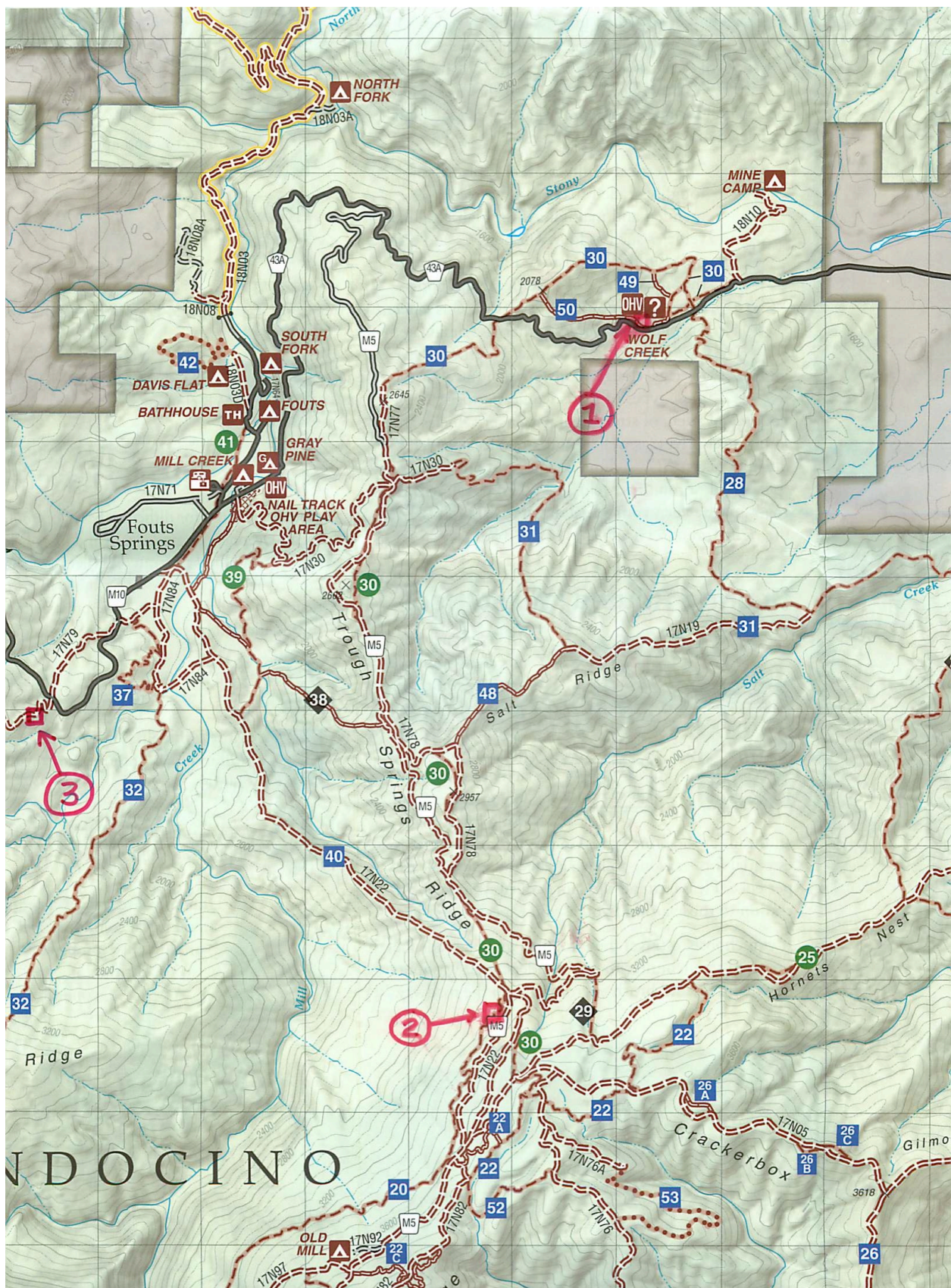


Figure 3. Benchmark Sampling Site Locations

Documentation of Benchmark Measurements for the Stonyford Area

Trail System		Date		By	
Most Recent Rainfall		Drying Conditions			
Benchmark – Site	Moisture		Strength		
	Outlet (D1)	Shoulder (D2)	Outlet (D1)	Shoulder (D2)	
1-1					
1-2					
1-3					
Average					
Site Exceeds Threshold		Yes / No	Yes / No	Yes / No	Yes / No
Benchmark Exceeds Threshold		Yes / No			
2-1					
2-2					
2-3					
Average					
Site Exceeds Threshold		Yes / No	Yes / No	Yes / No	Yes / No
Benchmark Exceeds Threshold		Yes / No			
3-1					
3-2					
3-3					
Average					
Site Exceeds Threshold		Yes / No	Yes / No	Yes / No	Yes / No
Benchmark Exceeds Threshold		Yes / No			
Notes on Trail Conditions:					
Decision: Open / Close			Approval		

An Evidence-based Process for Wet-weather Closures on the Upper Lake Ranger District, Mendocino National Forest

Introduction

This report is on one of four pilot studies conducted to test the effectiveness of evidence-based wet-weather closures on National Forests in California. The studies were funded by a grant from the CA OHV Commission. The objective of the grant was to examine existing criteria for wet-weather OHV trail closures, and propose alternative strategies for managing OHV trails under wet-weather conditions. The evidence-based process in this report can be used as an alternative to a seasonal closure or to a precipitation-based closure.

The process described in this report is based on a correlation of observed damage to OHV trails with measurements of soil moisture and soil strength. The threshold values for soil moisture and strength used in this report are based on actual data collected on Upper Lake District trails.

This report contains specific instructions on how to use measurements of soil moisture and soil strength to determine when to open or close trails. It is a set of implementation instructions. This report does not explain how the threshold values for the Upper Lake Ranger District were developed. That information, and more detailed information on wet-weather management of OHV trails, is provided in *Wet-weather Management of OHV Trails on National Forests in California (2014)*, of which this report is an Appendix.

The Process

The process includes six elements:

1. *Threshold values* are measurements of soil strength and soil moisture that are used to determine the risk of trail damage. When threshold values are exceeded, the risk of damage to trails is moderate to high.
2. *Benchmark sites* are sampling locations where measurements are made to determine whether or not threshold values are exceeded. Benchmark sites are selected to represent conditions across a whole trail system or a portion of it.
3. *Protocols for measurement and analysis* are specific instructions on how the measurements of soil strength and moisture are taken, and define how these measurements are interpreted to determine whether or not the threshold is exceeded.
4. *Decision tree* is a flowchart that specifies when benchmark sites are to be monitored and when to open or close trails.
5. *Documentation* A standardized form is used to document field measurements, calculations, and decisions to open or close trails. Completed forms can also be used as part of an implementation and effectiveness monitoring program.
6. *Forest Order* A legal document signed by the Forest Supervisor that specifies the conditions under which trails will be opened or closed and penalties for violations of the closure.

Threshold Values

Threshold values of soil moisture and soil strength for the Upper Lake RD are shown in Table 1. The thresholds are based on measurements and observations that were made on Upper Lake trails and are unique to the Upper Lake area. When these threshold values are exceeded, there

is a moderate to high risk that OHV traffic will cause damage to trail drainage structures and trail treads.

Measurement Type	Threshold
Soil Moisture Content (% by volume)	> 28.0
Soil Strength (psi)	< 130

Table 1. Threshold Values of Soil Moisture and Soil Strength for Upper Lake RD Trails¹

Benchmark Sites

Five benchmark sites have been selected to represent trail conditions on the Upper Lake Ranger District. The map on page 7 of this report shows the locations of the benchmark sites.

Measurement Protocols

Sampling Locations

At each benchmark site, twelve (12) measurements of soil strength and moisture are taken. The measurements are made at two sites on a drain dip structure: one set of measurements in the drain dip outlet (D1 in Figure 1), and one set on the first shoulder (D2 in Figure 1) of the dip structure. Each set includes three (3) measurements of soil moisture content, and three (3) measurements of soil strength. All measurements are taken within the third of the trail tread on the drain dip outlet side of the trail, and all measurements are made in the 0 to 2-inch surface layer of the tread.

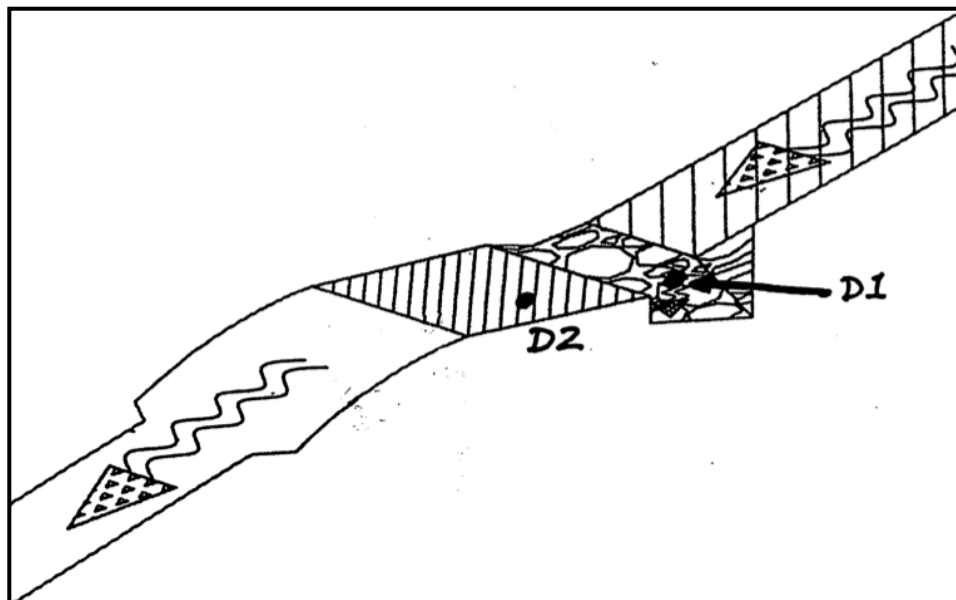


Figure 1. Drain Dip Showing Sample Locations

¹ Measurements above the threshold for moisture content, or below the threshold for soil strength, are defined as exceeding the threshold, and predict a moderate to high risk of damage to drainage structures and trail treads under OHV traffic.

Soil Moisture

Soil moisture is measured using the HH150 moisture meter fitted with the SM150 sensor. At sample site D1, prepare the surface by lightly scraping the top 1/8- to 1/4-inch of soil to create a flat surface. Use the insertion kit to create three sets of holes for the probe sensors. Insert the sensor until it is completely flush with the soil surface and then measure and record the soil moisture content. Repeat for sample site D2. The form should now have two sets of three moisture measurements.

If the soil is too hard and compacted to insert the moisture probe without the risk of damage to the electrodes, the soil moisture is probably well within the threshold. In this case, only measure soil strength with the penetrometer as described in the next section. Note on the form why moisture was not measured.

Soil Strength

After measuring soil moisture, return to the same two sites (D1 and D2) and measure soil strength using the penetrometer. Make the measurements at the same points where the moisture was measured, or as close as practical.

Insert the penetrometer with a steady and even pressure. If stones or roots are encountered, take additional measurements to get a consistent set of three readings for each site (D1 and D2). The form should now have four sets of three measurements; two sets for moisture and two sets for strength.

Threshold Determination

Thresholds for Individual Benchmark Sites

Averages of the measurements taken at D1 and D2 are used to determine whether or not each benchmark exceeds the threshold. Average each of the four sets of measurements and record this average on the form. Mark (circle yes or no) whether or not the average for each set exceeds the threshold.

Threshold for the Trail System

At the bottom of the form, note how many benchmark sites exceed the threshold. If the threshold is exceeded at one or more of the two benchmark sites, the trail system shall be closed or shall remain closed.

Where the measurements are very close to the threshold values, it may be appropriate to recommend opening or closing the trail system based on observed soil conditions, even though the threshold criteria have not been met. Record the observations and reasons for such a recommendation at the bottom of the form.

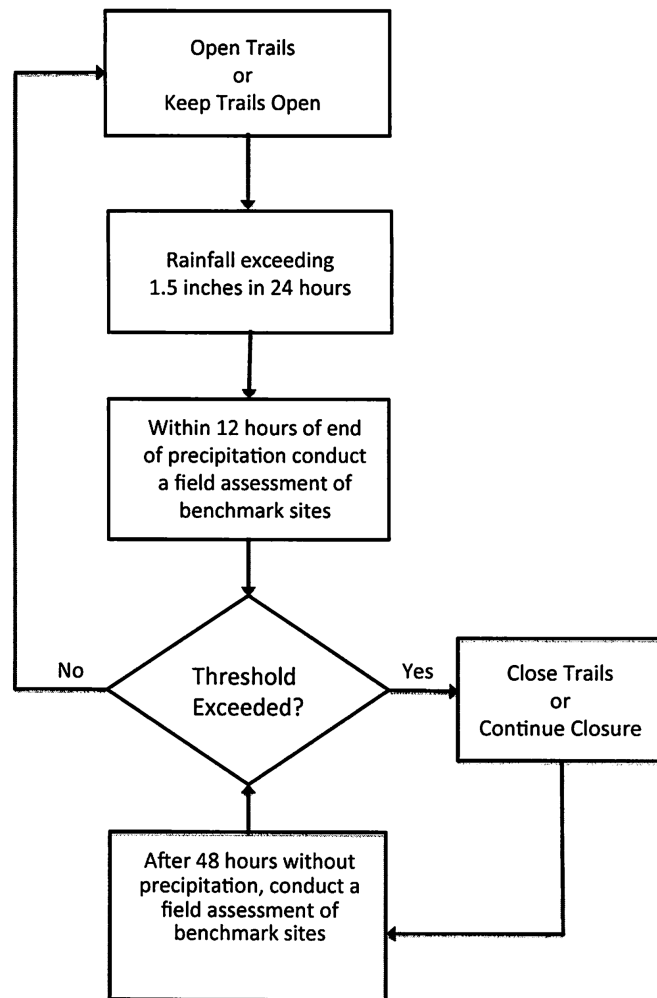
Decision Tree

The flowchart in Figure 2 shows when measurements of soil strength and moisture shall be taken, and how the threshold values at the benchmark sites affect decisions to open and close trails.

Monitoring

Review the completed forms annually to monitor the implementation and effectiveness of the closure policy.

Figure 2. Upper LakeTrail Closures



Additional Instructions for Measuring Soil Moisture and Strength

HH150 Moisture Meter with SM150 Moisture Sensor

The HH150 Moisture Meter with SM150 Moisture Sensor is simple to set up and use, and provides quick and highly accurate moisture readings. However, some care is required in its use, especially to avoid damaging the sensor rods.

Set Up

Insert the batteries. Use only good quality alkaline batteries. Remove the batteries when the meter will not be in use for an extended time period. Connect the SM150 sensor to the HH150 meter. Align connectors carefully before pushing the parts together. Screw together firmly.

With the meter OFF, press the right off-menu button. This wakes the meter and allows you to set the display readings. Set to % volumetric water content and to mineral soil. Then press **off** to save the current setting and turn the meter off. This is a one-time step unless the batteries are removed. If set up correctly, the moisture readout will show “mineral” and “% vol.”

Taking Readings

Clear away any stones and scrape the surface to create a flat surface to allow the sensor to make a full contact with the soil.

Remove the center pin from the 4-pin insertion tool and use the tool to create 3 holes in the soil. If the soil is firm, gently tap the block and pins with a hammer to create the holes. Remove the insertion pin tool carefully to avoid displacing or fracturing the soil.

Gently insert the SM150 rods into two of the holes punched by the insertion tool. The sensor rods must be fully inserted. Make sure the base of the sensor makes a good contact with the soil surface. Insert the rods slowly. If resistance is felt, it is probably a stone or pebble. Try a different set of two holes, or move to a new location. Avoid any pressure that will change the rod alignment.

With the meter OFF, press the left on-read button to take a reading. The reading will be instantaneous. The meter will sleep after about 30 seconds.

Care and Safety

- The pins used in the 4-pin insertion tool are extremely sharp and dangerous. Take care to keep track of its location so you do not accidentally step on it or place your hand on it. When not in use, place it on its side or with the pins partly in the soil to lessen the risk of punctures. Bright yellow tape—or bright paint—around the edge of the pin block will make the tool more visible in the field.
- The sensor rods of the SM150 are sharp to ease insertion. They can puncture skin, so care is advised.
- Do not touch the sensor rods or expose them to other sources of *static charge*, particularly when powered up or attached to the cable. An electrostatic discharge from your body can typically cause a temporary -10mV offset in sensor readings for up to one hour. At worst, it could even permanently damage the sensor.
- Do not pull the SM150 out of the soil by its cable.

Humboldt H-4120HA C.O.E. Cone Penetrometer

Penetrometer Adjustments and Maintenance

If treated carefully, as with any fine instrument, the cone penetrometer should require little maintenance or adjustment. Before using the penetrometer, check to see that the rod and cone tip are not loose, and that the handle is tight, especially if the penetrometer has been disassembled for transport. The handle is tightened with a set screw (wrench provided).

Taking Soil Strength Measurements

Loosen the dial lock knob and, while holding the penetrometer vertically in the air by the T-handle, set the dial to zero. Resetting the dial to zero may need to be done frequently to compensate for the effects of temperature changes on the proving ring.

Push the penetrometer into the soil slowly and steadily, keeping the pressure on the handle as even as possible. Over time, and with practice, consistent readings should be easy to achieve. To estimate the depth of penetration, the first six inches of the rod are marked with 1-inch wide knurled sections.

The dial on the penetrometer reads directly in pound-force per square inch (psi). When using a ½ inch 30-degree cone tip, it also reads cone index (ci) directly.

There are many models and styles of penetrometers. Other types will have slightly different operating instructions. For consistency, use a penetrometer with a ½ inch 30-degree cone tip that measures psi or ci.

Consistency

Consistency is important when making measurements and observations. A qualified professional should initially train persons making the measurements and observations. Training should include principles of soil behavior as it relates to OHV traffic; operation and maintenance of the moisture meter; use of the 4-pin insertion tool; operation and maintenance of the penetrometer; and visual indicators of tread failure.

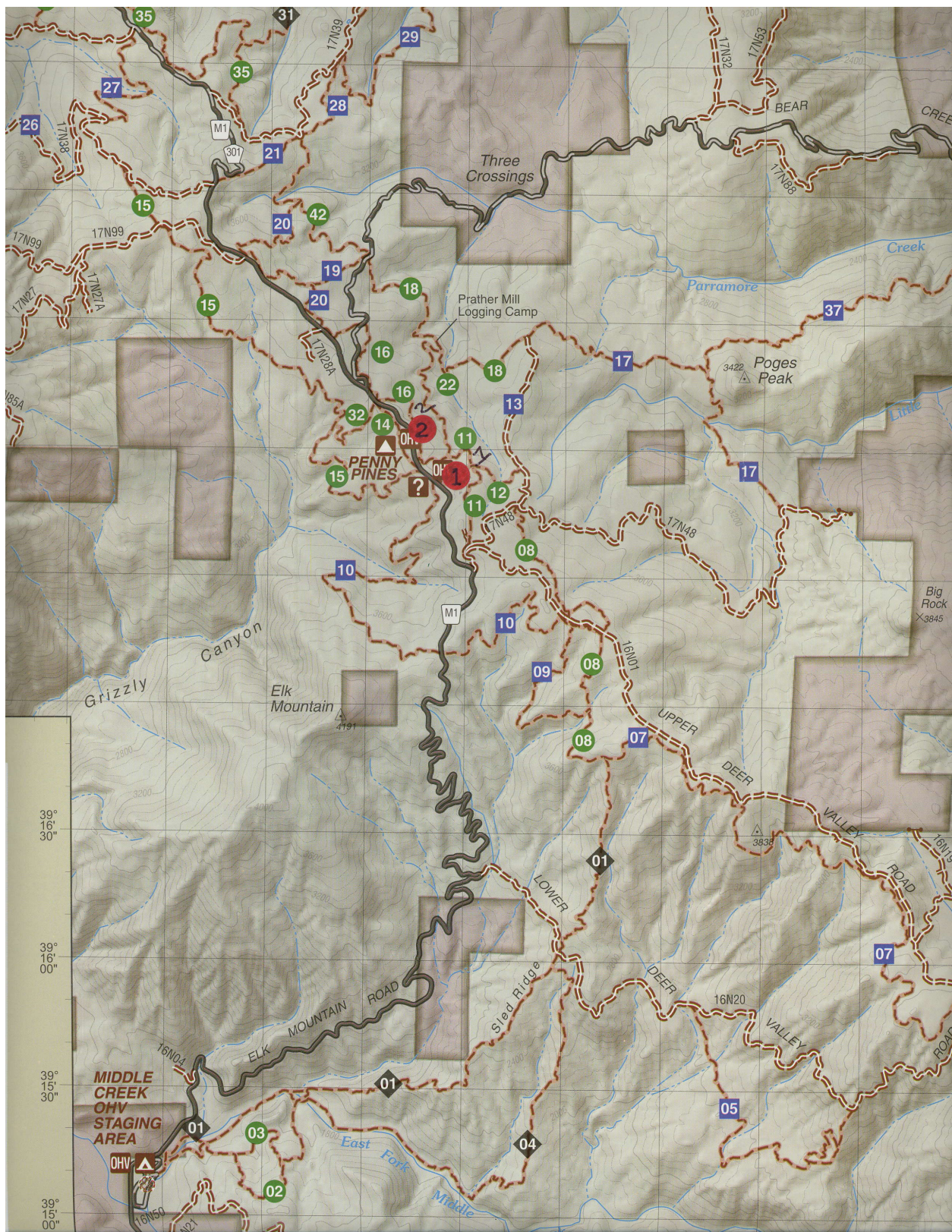


Figure 3. Benchmark Sampling Site Locations

Documentation of Benchmark Measurements for Upper Lake Ranger District

Trail System		Date		By	
Most Recent Rainfall		Drying Conditions			
Benchmark – Site	Moisture		Strength		
	Outlet (D1)	Shoulder (D2)	Outlet (D1)	Shoulder (D2)	
1-1					
1-2					
1-3					
Average					
Site Exceeds Threshold	Yes / No	Yes / No	Yes / No	Yes / No	
Benchmark Exceeds Threshold	Yes / No				
2-1					
2-2					
2-3					
Average					
Site Exceeds Threshold	Yes / No	Yes / No	Yes / No	Yes / No	
Benchmark Exceeds Threshold	Yes / No				
Notes on Trail Conditions:					
Decision: Open / Close			Approval		

An Evidence-based Process for Wet-weather Closures on the Sugar Pine OHV Area, Tahoe National Forest

Introduction

This report is on one of four pilot studies conducted to test the effectiveness of evidence-based wet-weather closures on National Forests in California. The studies were funded by a grant from the CA OHV Commission. The objective of the grant was to examine existing criteria for wet-weather OHV trail closures, and propose alternative strategies for managing OHV trails under wet-weather conditions. The evidence-based process in this report can be used as an alternative to a seasonal closure or to a precipitation-based closure.

The process described in this report is based on a correlation of observed damage to OHV trails with measurements of soil moisture and soil strength. The threshold values for soil moisture and strength used in this report are based on actual data collected on Sugar Pine area trails.

This report contains specific instructions on how to use measurements of soil moisture and soil strength to determine when to open or close trails. It is a set of implementation instructions. This report does not explain how the threshold values for the Sugar Pine area were developed. That information, and more detailed information on wet-weather management of OHV trails, is provided in *Wet-weather Management of OHV Trails on National Forests in California (2014)*, of which this report is an Appendix.

The Process

The process includes six elements:

1. *Threshold values* are measurements of soil strength and soil moisture that are used to determine the risk of trail damage. When threshold values are exceeded, the risk of damage to trails is moderate to high.
2. *Benchmark sites* are sampling locations where measurements are made to determine whether or not threshold values are exceeded. Benchmark sites are selected to represent conditions across a whole trail system or a portion of it.
3. *Protocols for measurement and analysis* are specific instructions on how the measurements of soil strength and moisture are taken, and define how these measurements are interpreted to determine whether or not the threshold is exceeded.
4. *Decision tree* is a flowchart that specifies when benchmark sites are to be monitored and when to open or close trails.
5. *Documentation* A standardized form is used to document field measurements, calculations, and decisions to open or close trails. Completed forms can also be used as part of an implementation and effectiveness monitoring program.
6. *Forest Order* A legal document signed by the Forest Supervisor that specifies the conditions under which trails will be opened or closed and penalties for violations of the closure.

Threshold Values

Threshold values of soil moisture and soil strength for the Sugar Pine area are shown in Table 1. The thresholds are based on measurements and observations that were made on Sugar Pine trails and are unique to the Sugar Pine area. When these threshold values are exceeded, there

is a moderate to high risk that OHV traffic will cause damage to trail drainage structures and trail treads.

Measurement Type	Threshold
Soil Moisture Content (% by volume)	> 40.0
Soil Strength (psi)	< 140

Table 1. Threshold Values of Soil Moisture and Soil Strength for Sugar Pine Area Trails¹

Benchmark Sites

Five benchmark sites have been selected to represent trail conditions on the Sugar Pine trail system. The map on page 7 of this report shows the locations of the benchmark sites.

Measurement Protocols

Sampling Locations

At each benchmark site, twelve (12) measurements of soil strength and moisture are taken. The measurements are made at two sites on a drain dip structure: one set of measurements in the drain dip outlet (D1 in Figure 1), and one set on the first shoulder (D2 in Figure 1) of the dip structure. Each set includes three (3) measurements of soil moisture content, and three (3) measurements of soil strength. All measurements are taken within the third of the trail tread on the drain dip outlet side of the trail, and all measurements are made in the 0 to 2-inch surface layer of the tread.

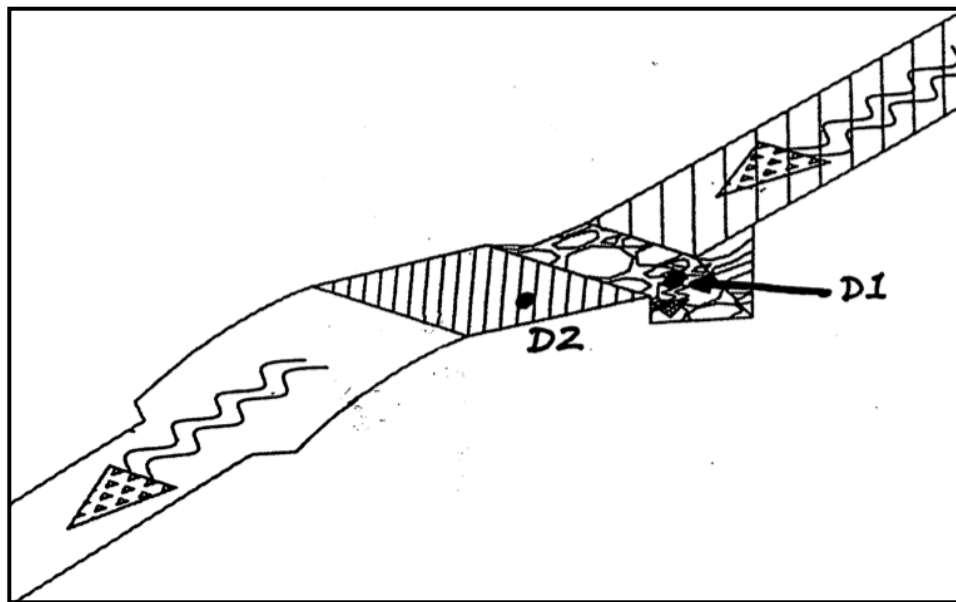


Figure 1. Drain Dip Showing Sample Locations

¹ Measurements above the threshold for moisture content, or below the threshold for soil strength, are defined as exceeding the threshold, and predict a moderate to high risk of damage to drainage structures and trail treads under OHV traffic.

Soil Moisture

Soil moisture is measured using the HH150 moisture meter fitted with the SM150 sensor. At sample site D1, prepare the surface by lightly scraping the top 1/8- to 1/4-inch of soil to create a flat surface. Use the insertion kit to create three sets of holes for the probe sensors. Insert the sensor until it is completely flush with the soil surface and then measure and record the soil moisture content. Repeat for sample site D2. The form should now have two sets of three moisture measurements.

If the soil is too hard and compacted to insert the moisture probe without the risk of damage to the electrodes, the soil moisture is probably well within the threshold. In this case, only measure soil strength with the penetrometer as described in the next section. Note on the form why moisture was not measured.

Soil Strength

After measuring soil moisture, return to the same two sites (D1 and D2) and measure soil strength using the penetrometer. Make the measurements at the same points where the moisture was measured, or as close as practical.

Insert the penetrometer with a steady and even pressure. If stones or roots are encountered, take additional measurements to get a consistent set of three readings for each site (D1 and D2). The form should now have four sets of three measurements; two sets for moisture and two sets for strength.

Threshold Determination

Thresholds for Individual Benchmark Sites

Averages of the measurements taken at D1 and D2 are used to determine whether or not each benchmark exceeds the threshold. Average each of the four sets of measurements and record this average on the form. Mark (circle yes or no) whether or not the average for each set exceeds the threshold.

Threshold for the Trail System

At the bottom of the form, note how many benchmark sites exceed the threshold. If the threshold is exceeded at one or more of the two benchmark sites, the trail system shall be closed or shall remain closed.

Where the measurements are very close to the threshold values, it may be appropriate to recommend opening or closing the trail system based on observed soil conditions, even though the threshold criteria have not been met. Record the observations and reasons for such a recommendation at the bottom of the form.

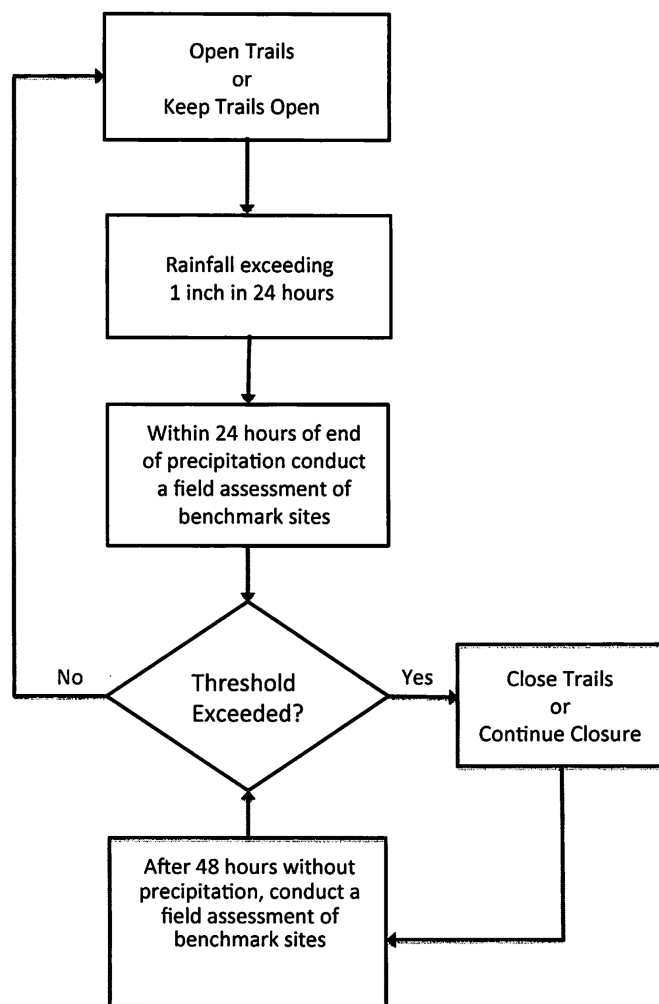
Decision Tree

The flowchart in Figure 2 shows when measurements of soil strength and moisture shall be taken, and how the threshold values at the benchmark sites affect decisions to open and close trails.

Monitoring

Review the completed forms annually to monitor the implementation and effectiveness of the closure policy.

Figure 2. Decision Tree for Sugar Pine OHV Area
Trail Closures



Additional Instructions for Measuring Soil Moisture and Strength

HH150 Moisture Meter with SM150 Moisture Sensor

The HH150 Moisture Meter with SM150 Moisture Sensor is simple to set up and use, and provides quick and highly accurate moisture readings. However, some care is required in its use, especially to avoid damaging the sensor rods.

Set Up

Insert the batteries. Use only good quality alkaline batteries. Remove the batteries when the meter will not be in use for an extended time period. Connect the SM150 sensor to the HH150 meter. Align connectors carefully before pushing the parts together. Screw together firmly.

With the meter OFF, press the right off-menu button. This wakes the meter and allows you to set the display readings. Set to % volumetric water content and to mineral soil. Then press **off** to save the current setting and turn the meter off. This is a one-time step unless the batteries are removed. If set up correctly, the moisture readout will show “mineral” and “% vol.”

Taking Readings

Clear away any stones and scrape the surface to create a flat surface to allow the sensor to make a full contact with the soil.

Remove the center pin from the 4-pin insertion tool and use the tool to create 3 holes in the soil. If the soil is firm, gently tap the block and pins with a hammer to create the holes. Remove the insertion pin tool carefully to avoid displacing or fracturing the soil.

Gently insert the SM150 rods into two of the holes punched by the insertion tool. The sensor rods must be fully inserted. Make sure the base of the sensor makes a good contact with the soil surface. Insert the rods slowly. If resistance is felt, it is probably a stone or pebble. Try a different set of two holes, or move to a new location. Avoid any pressure that will change the rod alignment.

With the meter OFF, press the left on-read button to take a reading. The reading will be instantaneous. The meter will sleep after about 30 seconds.

Care and Safety

- The pins used in the 4-pin insertion tool are extremely sharp and dangerous. Take care to keep track of its location so you do not accidentally step on it or place your hand on it. When not in use, place it on its side or with the pins partly in the soil to lessen the risk of punctures. Bright yellow tape—or bright paint—around the edge of the pin block will make the tool more visible in the field.
- The sensor rods of the SM150 are sharp to ease insertion. They can puncture skin, so care is advised.
- Do not touch the sensor rods or expose them to other sources of *static charge*, particularly when powered up or attached to the cable. An electrostatic discharge from your body can typically cause a temporary -10mV offset in sensor readings for up to one hour. At worst, it could even permanently damage the sensor.
- Do not pull the SM150 out of the soil by its cable.

Humboldt H-4120HA C.O.E. Cone Penetrometer

Penetrometer Adjustments and Maintenance

If treated carefully, as with any fine instrument, the cone penetrometer should require little maintenance or adjustment. Before using the penetrometer, check to see that the rod and cone tip are not loose, and that the handle is tight, especially if the penetrometer has been disassembled for transport. The handle is tightened with a set screw (wrench provided).

Taking Soil Strength Measurements

Loosen the dial lock knob and, while holding the penetrometer vertically in the air by the T-handle, set the dial to zero. Resetting the dial to zero may need to be done frequently to compensate for the effects of temperature changes on the proving ring.

Push the penetrometer into the soil slowly and steadily, keeping the pressure on the handle as even as possible. Over time, and with practice, consistent readings should be easy to achieve. To estimate the depth of penetration, the first six inches of the rod are marked with 1-inch wide knurled sections.

The dial on the penetrometer reads directly in pound-force per square inch (psi). When using a ½ inch 30-degree cone tip, it also reads cone index (ci) directly.

There are many models and styles of penetrometers. Other types will have slightly different operating instructions. For consistency, use a penetrometer with a ½ inch 30-degree cone tip that measures psi or ci.

Consistency

Consistency is important when making measurements and observations. A qualified professional should initially train persons making the measurements and observations. Training should include principles of soil behavior as it relates to OHV traffic; operation and maintenance of the moisture meter; use of the 4-pin insertion tool; operation and maintenance of the penetrometer; and visual indicators of tread failure.

Documentation of Benchmark Measurements for the Sugar Pine OHV Area

Trail System		Date		By	
Most Recent Rainfall		Drying Conditions			
Benchmark – Site	Moisture		Strength		
	Outlet (D1)	Shoulder (D2)	Outlet (D1)	Shoulder (D2)	
1-1					
1-2					
1-3					
Average					
Site Exceeds Threshold	Yes / No	Yes / No	Yes / No	Yes / No	
Benchmark Exceeds Threshold	Yes / No				
2-1					
2-2					
2-3					
Average					
Site Exceeds Threshold	Yes / No	Yes / No	Yes / No	Yes / No	
Benchmark Exceeds Threshold	Yes / No				
Notes on Trail Conditions:					
Decision: Open / Close			Approval		

Record	District	Date 2014	Location	Site	Depth	CLASS	psi	% V	Moisture			W/D	Last PPTN	Condition - Soil Type - Notes
1001	Pozo	15-Mar	N35-21,47 W120-20,16	tread	0-2	5	25	44.3	46.1	42.5	3.6	w		near a spring area; very puddled
1002	Pozo	15-Mar	N35-21,47 W120-20,17	tread	0-2	5	30	42.5	43.9	41.1	2.8	w		near a spring area; very puddled
1003	Pozo	15-Mar	N35-21,47 W120-20,18	tread	0-2	5	40	42.5	43.2	41.7	1.5	w		near a spring area; very puddled
1004	Pozo	15-Mar	N35-21,47 W120-20,19	tread	0-2	4	90	34.6	34.8	34.4	0.4	w		near a spring area; puddled
1005	Pozo	15-Mar	N35-21,47 W120-20,20	tread	0-2	4	110	33.2	33.2	33.1	0.1	w		near a spring area; puddled
1006	Pozo	15-Mar	N35-21,47 W120-20,21	tread	0-2	4	92	40.1	41.2	39.0	2.2	w		near a spring area; puddled
1007	Pozo	15-Mar	N35-21,47 W120-20,22	tread	0-2	3	125	31.6	29.4	33.8	-4.4	w		near a spring area; threshold
1008	Pozo	15-Mar	N35-21,47 W120-20,23	tread	0-2	3	160	29.7	29.2	30.2	-1.0	w		near a spring area; threshold
1009	Pozo	15-Mar	N35-21,47 W120-20,24	tread	0-2	3	165	29.7	30.5	28.9	1.6	w		near a spring area; threshold
1010	Pozo	15-Mar	N35-21,47 W120-20,25	tread	0-2	2	250	19.9	21.0	18.7	2.3	w		near a spring area; very firm
1011	Pozo	15-Mar	N35-21,47 W120-20,26	tread	0-2	2	310	17.4	17.6	17.1	0.5	w		near a spring area; very firm
1012	Pozo	15-Mar	N35-21,47 W120-20,27	tread	0-2	2	325	21.7	21.9	21.5	0.4	w		near a spring area; very firm
1013	Pozo	15-Mar	N35-21,47 W120-20,28	tread	0-2	1	320	13.1	12.4	13.7	-1.3	w		near a spring area; hard
1014	Pozo	15-Mar	N35-21,47 W120-20,29	tread	0-2	1	321	11.7	11.8	11.6	0.2	w		near a spring area; hard
1015	Pozo	15-Mar	N35-21,47 W120-20,30	tread	0-2	1	346	11.1	8.2	14.0	-5.8	w		near a spring area; hard
1016	Pozo	15-Mar	N35-21,47 W120-20,31	tread	2-4	5	95	29.4	30.0	28.7	1.3	w		wet; 4-inch rut
1017	Pozo	15-Mar	N35-21,47 W120-20,32	tread	2-4	5	78	33.0	32.6	33.4	-0.8	w		wet; 4-inch rut
1018	Pozo	15-Mar	N35-21,47 W120-20,33	tread	2-4	5	82	33.7	32.7	34.6	-1.9	w		wet; 4-inch rut
1019	Pozo	15-Mar	N35-21,47 W120-20,34	tread	2-4	4	192	24.4	21.9	26.8	-4.9	w		wet; rut about 2-inch deep
1020	Pozo	15-Mar	N35-21,47 W120-20,35	tread	2-4	4	216	20.3	18.6	21.9	-3.3	w		wet; rut about 2-inch deep
1021	Pozo	15-Mar	N35-21,47 W120-20,36	tread	2-4	4	212	26.8	27.9	25.7	2.2	w		wet; rut about 2-inch deep
1022	Pozo	15-Mar	N35-21,47 W120-20,37	tread	2-4	3	135	27.3	25.5	29.1	-3.6	w		damp; tread imprint; no rut
1023	Pozo	15-Mar	N35-21,47 W120-20,38	tread	2-4	3	126	23.2	23.2	23.2	0.0	w		damp; tread imprint; no rut
1024	Pozo	15-Mar	N35-21,47 W120-20,39	tread	2-4	3	148	27.0	26.1	27.9	-1.8	w		damp; tread imprint; no rut
1025	Pozo	15-Mar	N35-21,47 W120-20,40	tread	2-4	2	350	13.3	10.6	15.9	-5.3	w		looks damp; no impact
1026	Pozo	15-Mar	N35-21,47 W120-20,41	tread	2-4	2	365	12.1	13.2	10.9	2.3	w		looks damp; no impact
1027	Pozo	15-Mar	N35-21,47 W120-20,42	tread	2-4	2	370	12.5	14.2	10.8	3.4	w		looks damp; no impact
1028	Pozo	15-Mar	N35-21,47 W120-20,43	tread	2-4	1	256	12.8	13.6	12.0	1.6	w		looks dry; no impact
1029	Pozo	15-Mar	N35-21,47 W120-20,44	tread	2-4	1	264	21.0	19.1	22.9	-3.8	w		looks dry; no impact
1030	Pozo	15-Mar	N35-21,47 W120-20,45	tread	2-4	1	274	21.7	21.4	22.0	-0.6	w		looks dry; no impact
1031	Pozo	15-Mar	N35-21,47 W120-20,46	tread	4-6	5	140	23.7	22.5	24.9	-2.4	w		more sandy with depth; depth measurments affected by sand
1032	Pozo	15-Mar	N35-21,47 W120-20,47	tread	4-6	5	129	22.7	22.2	23.2	-1.0	w		more sandy with depth; depth measurments affected by sand
1033	Pozo	15-Mar	N35-21,47 W120-20,48	tread	4-6	5	124	22.9	23.6	22.1	1.5	w		more sandy with depth; depth measurments affected by sand
1034	Pozo	15-Mar	N35-21,47 W120-20,49	tread	4-6	4	320	16.4	16.0	16.7	-0.7	w		more sandy with depth; depth measurments affected by sand
1035	Pozo	15-Mar	N35-21,47 W120-20,50	tread	4-6	4	337	14.8	14.2	15.4	-1.2	w		more sandy with depth; depth measurments affected by sand
1036	Pozo	15-Mar	N35-21,47 W120-20,51	tread	4-6	4	290	17.5	16.7	18.3	-1.6	w		more sandy with depth; depth measurments affected by sand
1037	Pozo	15-Mar	N35-21,47 W120-20,52	tread	4-6	3	270	21.3	19.2	23.4	-4.2	w		more sandy with depth; depth measurments affected by sand
1038	Pozo	15-Mar	N35-21,47 W120-20,53	tread	4-6	3	276	24.3	23.0	25.6	-2.6	w		more sandy with depth; depth measurments affected by sand
1039	Pozo	15-Mar	N35-21,47 W120-20,54	tread	4-6	3	271	18.6	20.9	16.3	4.6	w		more sandy with depth; depth measurments affected by sand
1040	Pozo	15-Mar	N35-21,47 W120-20,55	tread	4-6	2	260	15.7	14.4	16.9	-2.5	w		more sandy with depth; depth measurments affected by sand
1041	Pozo	15-Mar	N35-21,47 W120-20,56	tread	4-6	2	290	9.5	8.7	10.3	-1.6	w		more sandy with depth; depth measurments affected by sand
1042	Pozo	15-Mar	N35-21,47 W120-20,57	tread	4-6	2	190	15.1	12.1	18.0	-5.9	w		more sandy with depth; depth measurments affected by sand
1043	Pozo	15-Mar	N35-21,47 W120-20,58	tread	4-6	1	325	25.0	24.1	25.8	-1.7	w		more sandy with depth; depth measurments affected by sand
1044	Pozo	15-Mar	N35-21,47 W120-20,59	tread	4-6	1	249	22.5	20.2	24.8	-4.6	w		more sandy with depth; depth measurments affected by sand

Record	District	Date 2014	Location	Site	Depth	CLASS	psi	% V	Moisture			W/D	Last PPTN	Condition - Soil Type - Notes
1045	Pozo	15-Mar	N35-21,47 W120-20,60	tread	4-6	1	310	21.6	18.8	24.3	-5.5	w		more sandy with depth; depth measurments affected by sand
1046	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	5	25	35.6	35.6			w	3 days	Tower, 16E24
1047	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	5	30	34.8	34.8			w	3 days	Tower, 16E24
1048	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	5	35	33.4	33.4			w	3 days	Tower, 16E24
1049	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	4	97	26.8	26.8			w	3 days	Tower, 16E24
1050	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	4	110	30.2	30.2			w	3 days	Tower, 16E24
1051	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	4	125	26.8	26.8			w	3 days	Tower, 16E24
1052	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	3	123	17.0	17.0			w	3 days	Tower, 16E24
1053	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	3	136	15.3	15.3			w	3 days	Tower, 16E24
1054	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	3	156	10.4	10.4			w	3 days	Tower, 16E24
1055	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	2	196	8.6	8.6			w	3 days	Tower, 16E24
1056	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	2	198	9.1	9.1			w	3 days	Tower, 16E24
1057	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	2	195	9.8	9.8			w	3 days	Tower, 16E24
1058	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	1	222	7.0	7.0			w	3 days	Tower, 16E24
1059	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	1	256	9.0	9.0			w	3 days	Tower, 16E24
1060	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	0-2	1	244	7.6	7.6			w	3 days	Tower, 16E24
1061	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	5	245	32.6	32.6			w	3 days	Tower, 16E24
1062	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	5	255	32.5	32.5			w	3 days	Tower, 16E24
1063	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	5	211	33.0	33.0			w	3 days	Tower, 16E24
1064	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	4	260	12.0	12.0			w	3 days	Tower, 16E24
1065	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	4	308	12.2	12.2			w	3 days	Tower, 16E24
1066	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	4	264	11.6	11.6			w	3 days	Tower, 16E24
1067	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	3	340	10.6	10.6			w	3 days	Tower, 16E24
1068	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	3	330	9.4	9.4			w	3 days	Tower, 16E24
1069	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	3	370	10.8	10.8			w	3 days	Tower, 16E24
1070	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	2	356	3.4	3.4			w	3 days	Tower, 16E24
1071	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	2	377	6.4	6.4			w	3 days	Tower, 16E24
1072	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	2	354	3.7	3.7			w	3 days	Tower, 16E24
1073	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	1	430	7.2	7.2			w	3 days	Tower, 16E24
1074	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	1	445	4.4	4.4			w	3 days	Tower, 16E24
1075	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	2-4	1	442	5.1	5.1			w	3 days	Tower, 16E24
1076	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	5	484	9.6	9.6			w	3 days	Tower, 16E24
1077	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	5	465	9.7	9.7			w	3 days	Tower, 16E24
1078	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	5	510	9.6	9.6			w	3 days	Tower, 16E24
1079	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	4	397	8.2	8.2			w	3 days	Tower, 16E24
1080	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	4	401	7.1	7.1			w	3 days	Tower, 16E24
1081	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	4	505	6.9	6.9			w	3 days	Tower, 16E24
1082	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	3	396	7.2	7.2			w	3 days	Tower, 16E24
1083	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	3	474	6.3	6.3			w	3 days	Tower, 16E24
1084	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	3	469	8.6	8.6			w	3 days	Tower, 16E24
1085	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	2	491	5.4	5.4			w	3 days	Tower, 16E24
1086	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	2	495	4.6	4.6			w	3 days	Tower, 16E24
1087	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	2	498	5.4	5.4			w	3 days	Tower, 16E24
1088	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	1	493	1.5	1.5			w	3 days	Tower, 16E24

Record	District	Date 2014	Location	Site	Depth	CLASS	psi	% V	Moisture			W/D	Last PPTN	Condition - Soil Type - Notes
1089	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	1	452	0.2	0.2			w	3 days	Tower, 16E24
1090	Pozo	20-Mar	35-21/16,8 120-20/52,1	tread	4-6	1	495	1.1	1.1			w	3 days	Tower, 16E24
2091	Grindstone	18-Mar	Trail #14	tread	0-2	5	42	45.0		45.0		w		spring at site; stony soil
2092	Grindstone	18-Mar	Trail #14	tread	0-2	5	38	51.8		51.8		w		spring at site; stony soil
2093	Grindstone	18-Mar	Trail #14	tread	0-2	5	24	45.8		45.8		w		spring at site; stony soil
2094	Grindstone	18-Mar	Trail #14	tread	0-2	4	60	27.0		27.0		w		spring at site; stony soil
2095	Grindstone	18-Mar	Trail #14	tread	0-2	4	48	27.4		27.4		w		spring at site; stony soil
2096	Grindstone	18-Mar	Trail #14	tread	0-2	4	64	37.4		37.4		w		spring at site; stony soil
2097	Grindstone	18-Mar	Trail #14	tread	0-2	3	120	46.3		46.3		w		spring at site; stony soil
2098	Grindstone	18-Mar	Trail #14	tread	0-2	3	140	44.3		44.3		w		spring at site; stony soil
2099	Grindstone	18-Mar	Trail #14	tread	0-2	3	138	43.6		43.6		w		spring at site; stony soil
2100	Grindstone	18-Mar	Trail #14	tread	0-2	2	190	43.7		43.7		w		spring at site; stony soil
2101	Grindstone	18-Mar	Trail #14	tread	0-2	2	185	43.8		43.8		w		spring at site; stony soil
2102	Grindstone	18-Mar	Trail #14	tread	0-2	2	178	47.4		47.4		w		spring at site; stony soil
2103	Grindstone	18-Mar	Trail #14	tread	0-2	1	260	17.2		17.2		w		spring at site; stony soil
2104	Grindstone	18-Mar	Trail #14	tread	0-2	1	280	14.6		14.6		w		spring at site; stony soil
2105	Grindstone	18-Mar	Trail #14	tread	0-2	1	240	15.5		15.5		w		spring at site; stony soil
2106	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	5	50	35.2		35.2		d		rocky base; strength affected by rocks; photos 2202-2205
2107	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	5	45	34.4		34.4		d		rocky base; strength affected by rocks; photos 2202-2206
2108	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	5	50	36.5		36.5		d		rocky base; strength affected by rocks; photos 2202-2207
2109	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	4	80	30.4		30.4		d		rocky base; strength affected by rocks; photos 2202-2208
2110	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	4	80	28.2		28.2		d		rocky base; strength affected by rocks; photos 2202-2209
2111	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	4	75	28.2		28.2		d		rocky base; strength affected by rocks; photos 2202-2210
2112	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	3	155	27.9		27.9		d		rocky base; strength affected by rocks; photos 2202-2211
2113	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	3	160	29.1		29.1		d		rocky base; strength affected by rocks; photos 2202-2212
2114	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	3	180	23.6		23.6		d		rocky base; strength affected by rocks; photos 2202-2213
2115	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	2	160	24.0		24.0		d		rocky base; strength affected by rocks; photos 2202-2214
2116	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	2	160	23.3		23.3		d		rocky base; strength affected by rocks; photos 2202-2215
2117	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	2	180	24.9		24.9		d		rocky base; strength affected by rocks; photos 2202-2216
2118	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	1	185	17.1		17.1		d		rocky base; strength affected by rocks; photos 2202-2217
2119	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	1	200	13.1		13.1		d		rocky base; strength affected by rocks; photos 2202-2218
2120	Grindstone	11-Apr	Trail #6, Lady Bug	dip	0-2	1	250	13.3		13.3		d		rocky base; strength affected by rocks; photos 2202-2219
2121	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	5	85	38.3		38.3		d		strength affected by rocky base
2122	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	5	90	34.1		34.1		d		strength affected by rocky base
2123	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	5	90	24.8		24.8		d		strength affected by rocky base
2124	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	4	80	31.2		31.2		d		strength affected by rocky base
2125	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	4	100	28.0		28.0		d		strength affected by rocky base
2126	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	4	120	30.3		30.3		d		strength affected by rocky base
2127	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	3	180	25.4		25.4		d		strength affected by rocky base
2128	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	3	170	18.0		18.0		d		strength affected by rocky base
2129	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	3	220	20.6		20.6		d		strength affected by rocky base
2130	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	2	165	31.7		31.7		d		strength affected by rocky base
2131	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	2	190	26.2		26.2		d		strength affected by rocky base
2132	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	2	185	30.3		30.3		d		strength affected by rocky base

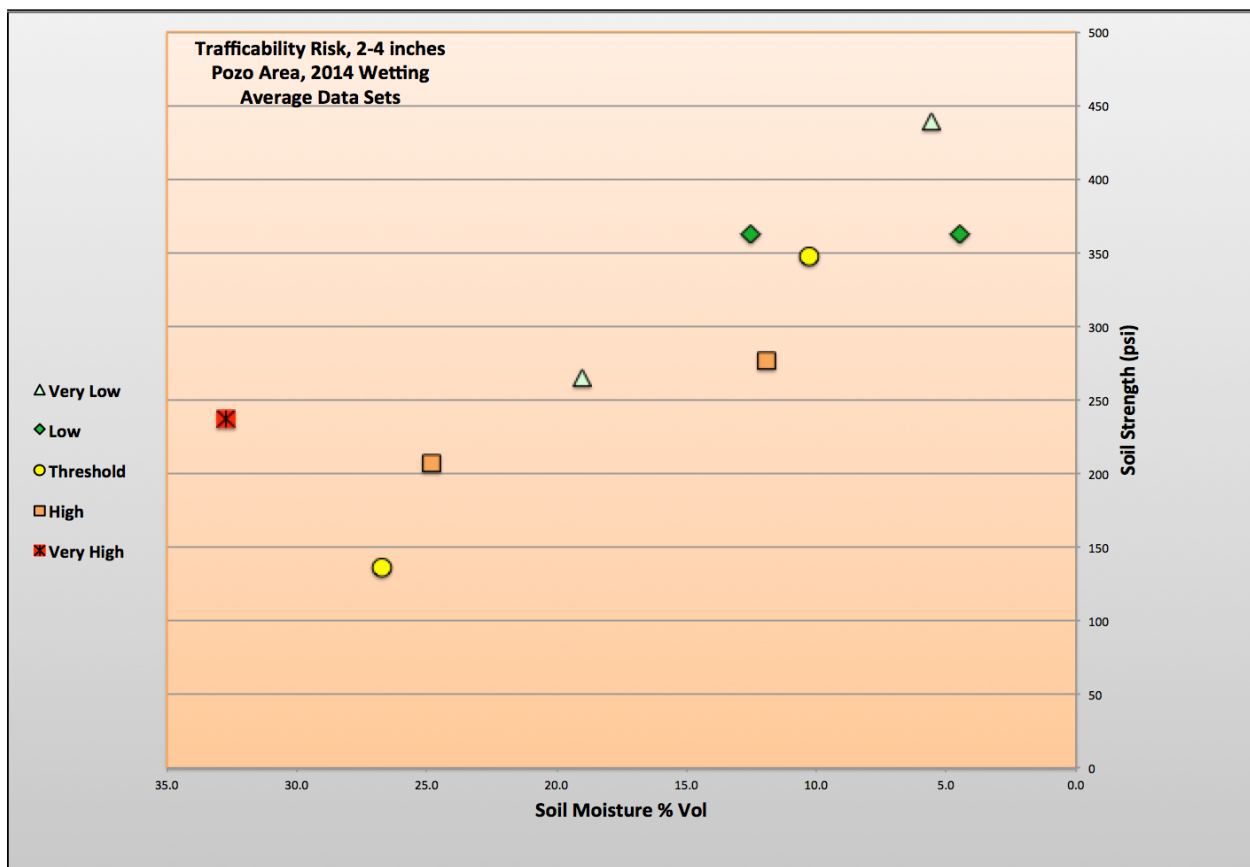
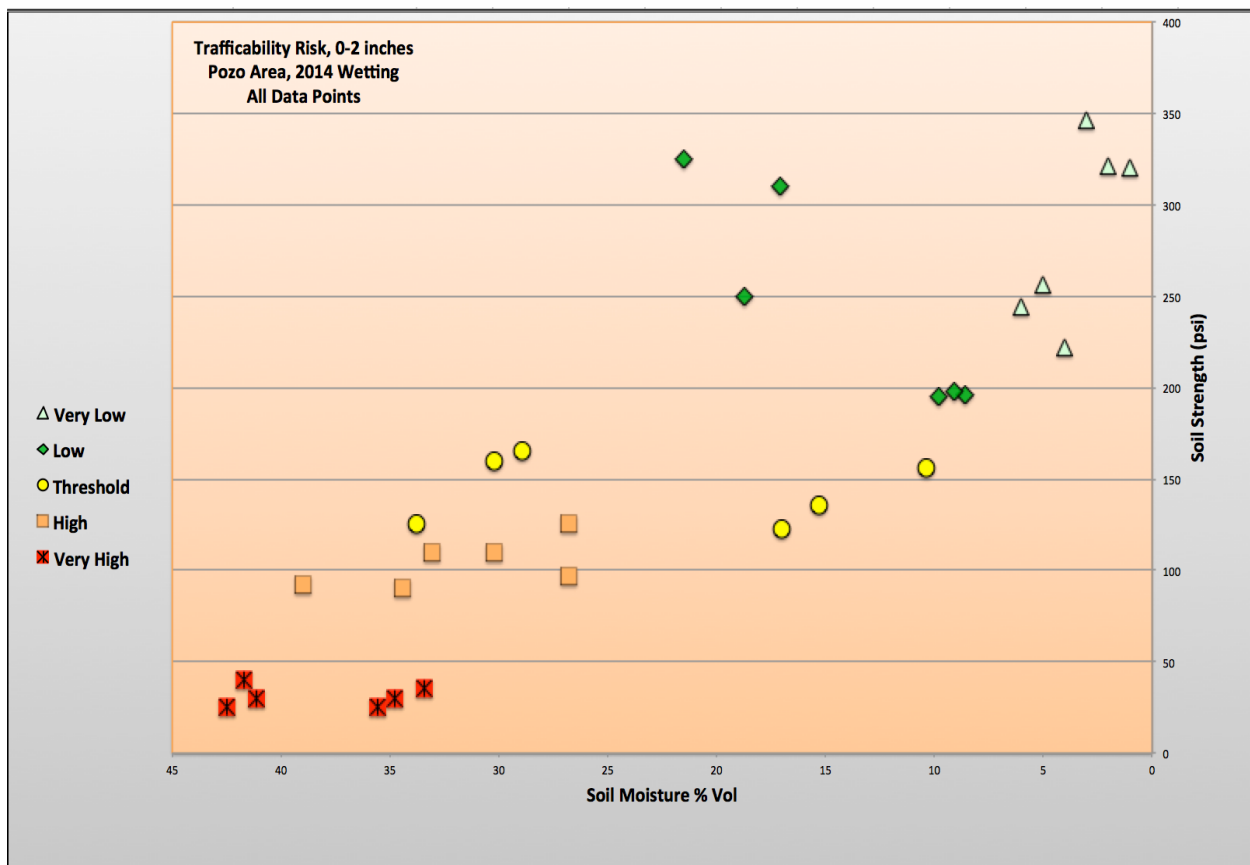
Record	District	Date 2014	Location	Site	Depth	CLASS	psi	% V	Moisture			W/D	Last PPTN	Condition - Soil Type - Notes
2133	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	1	250	18.1		18.1		d		strength affected by rocky base
2134	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	1	235	18.2		18.2		d		strength affected by rocky base
2135	Grindstone	11-Apr	Trail #6, Lady Bug	dip	2-4	1	280	14.0		14.0		d		strength affected by rocky base
2136	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	5	30	31.1				d		moslty in a road; photos 2198-2201
2137	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	5	50	34.6	34.6			d		moslty in a road; photos 2198-2202
2138	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	5	45	38.8	38.8			d		moslty in a road; photos 2198-2203
2139	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	4	130	25.0	25.0			d		moslty in a road; photos 2198-2204
2140	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	4	120	25.7	25.7			d		moslty in a road; photos 2198-2205
2141	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	4	115	28.1	28.1			d		moslty in a road; photos 2198-2206
2142	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	3	175	36.2	36.2			d		moslty in a road; photos 2198-2207
2143	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	3	170	36.1	36.1			d		moslty in a road; photos 2198-2208
2144	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	3	160	31.7	31.7			d		moslty in a road; photos 2198-2209
2145	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	2	235	26.6	26.6			d		moslty in a road; photos 2198-2210
2146	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	2	245	26.8	26.8			d		moslty in a road; photos 2198-2211
2147	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	2	240	20.8	20.8			d		moslty in a road; photos 2198-2212
2148	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	1	220	14.5	14.5			d		moslty in a road; photos 2198-2213
2149	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	1	250	13.7	13.7			d		moslty in a road; photos 2198-2214
2150	Grindstone	11-Apr	Trail #6, Lady Bug	tread	0-2	1	280	11.2	11.2			d		moslty in a road; photos 2198-2215
2151	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	5	55	40.3	40.3			d		hard bottom
2152	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	5	45	41.8	41.8			d		hard bottom
2153	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	5	50	47.6	47.6			d		hard bottom
2154	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	4	160	20.3	20.3			d		hard bottom
2155	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	4	170	20.4	20.4			d		hard bottom
2156	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	4	175	21.8	21.8			d		hard bottom
2157	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	3	220	16.8	16.8			d		hard bottom
2158	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	3	100	16.6	16.6			d		hard bottom
2159	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	3	190	13.0	13.0			d		hard bottom
2160	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	2	180	17.8	17.8			d		hard bottom
2161	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	2	230	15.4	15.4			d		hard bottom
2162	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	2	240	20.0	20.0			d		hard bottom
2163	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	1	280	14.4	14.4			d		hard bottom
2164	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	1	230	14.8	14.8			d		hard bottom
2165	Grindstone	11-Apr	Trail #6, Lady Bug	tread	2-4	1	290	14.0	14.0			d		hard bottom
2166	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	5	55	29.2	29.2			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 454
2167	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	5	20	29.9	29.9			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 455
2168	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	5	45	27.8	27.8			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 456
2169	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	4	100	24.2	24.2			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 457
2170	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	4	95	21.0	21.0			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 458
2171	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	4	75	18.2	18.2			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 459
2172	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	3	160	26.7	26.7			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 460
2173	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	3	180	27.4	27.4			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 461
2174	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	3	160	28.2	28.2			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 462
2175	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	2	235	19.6	19.6			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 463
2176	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	2	220	18.9	18.9			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 464

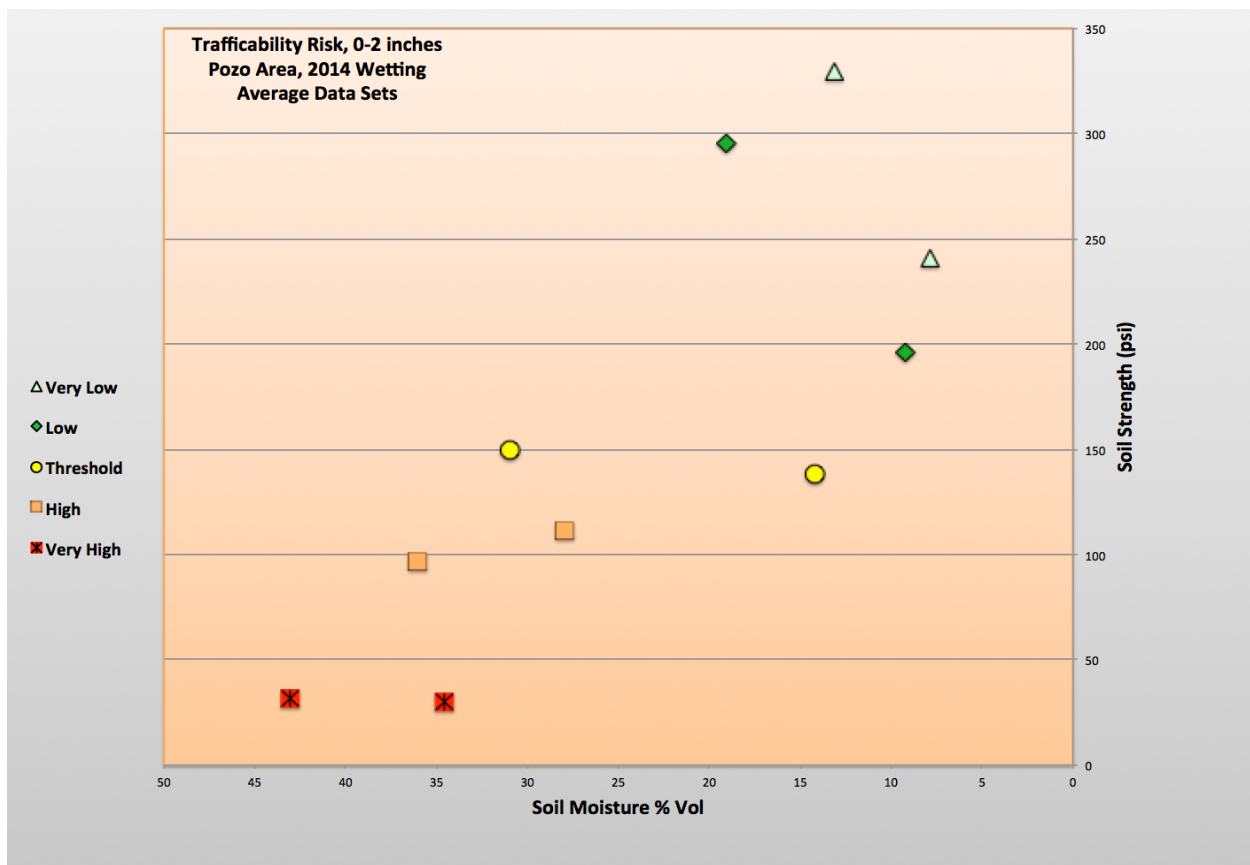
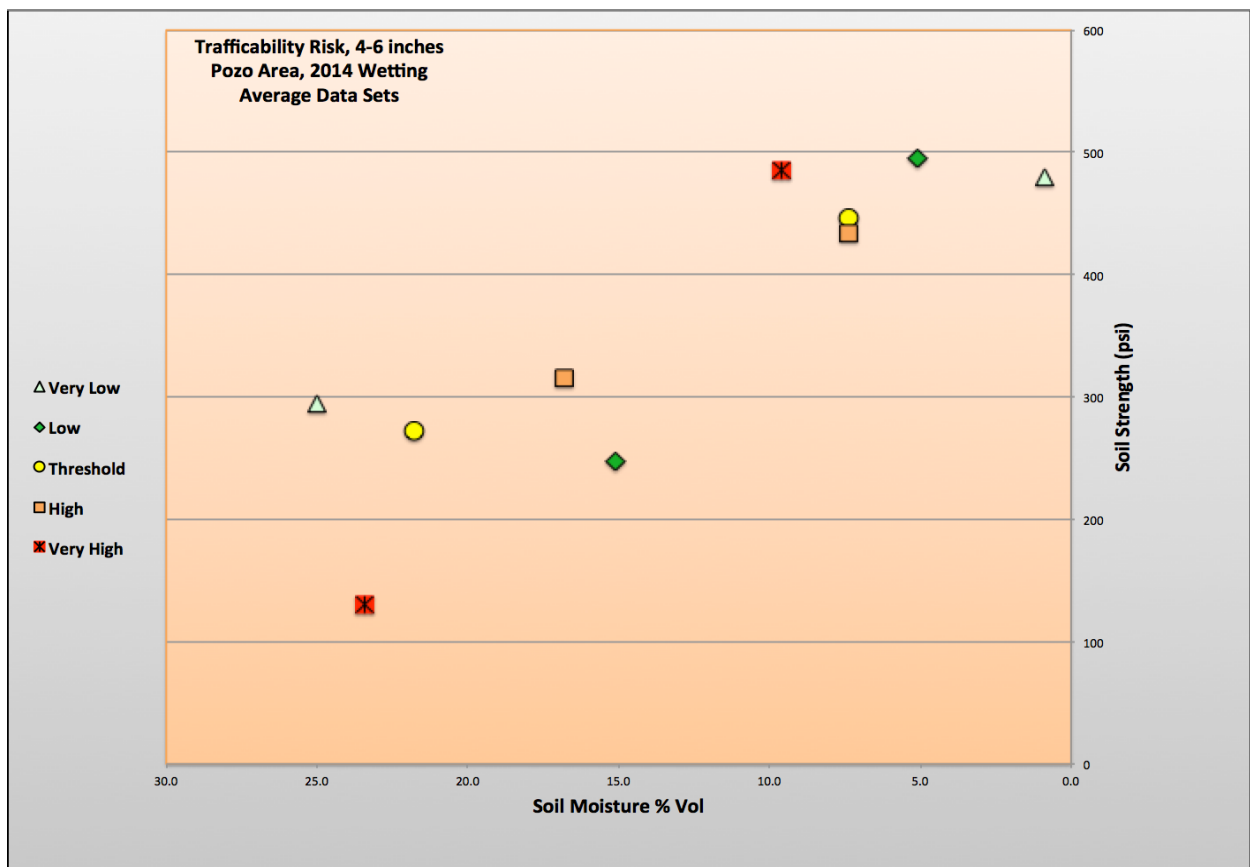
Record	District	Date 2014	Location	Site	Depth	CLASS	psi	% V	Moisture			W/D	Last PPTN	Condition - Soil Type - Notes
2177	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	2	230	17.2	17.2			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 465
2178	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	1	280	15.4	15.4			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 466
2179	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	1	300	14.2	14.2			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 467
2180	Grindstone	11-Apr	Trail #33, Mill Creek	tread	0-2	1	275	12.3	12.3			d	couple wks	near a spring; N39-19.303, W122-42.500 WP 468
2181	Grindstone	18-Mar	Trail #15	tread	0-2	5	55	45.4	45.4			d		at a crossing; N39-16,42,0 W122-43,12,1
2182	Grindstone	18-Mar	Trail #15	tread	0-2	5	40	54.7	54.7			d		at a crossing; N39-16,42,0 W122-43,12,1
2183	Grindstone	18-Mar	Trail #15	tread	0-2	5	35	55.6	55.6			d		at a crossing; N39-16,42,0 W122-43,12,1
2184	Grindstone	18-Mar	Trail #15	tread	0-2	4	95	33.5	33.5			d		at a crossing; N39-16,42,0 W122-43,12,1
2185	Grindstone	18-Mar	Trail #15	tread	0-2	4	80	31.8	31.8			d		at a crossing; N39-16,42,0 W122-43,12,1
2186	Grindstone	18-Mar	Trail #15	tread	0-2	4	95	41.9	41.9			d		at a crossing; N39-16,42,0 W122-43,12,1
2187	Grindstone	18-Mar	Trail #15	tread	0-2	3	125	33.8	33.8			d		at a crossing; N39-16,42,0 W122-43,12,1
2188	Grindstone	18-Mar	Trail #15	tread	0-2	3	135	20.0	20.0			d		at a crossing; N39-16,42,0 W122-43,12,1
2189	Grindstone	18-Mar	Trail #15	tread	0-2	3	155	20.2	20.2			d		at a crossing; N39-16,42,0 W122-43,12,1
2190	Grindstone	18-Mar	Trail #15	tread	0-2	2	220	22.8	22.8			d		at a crossing; N39-16,42,0 W122-43,12,1
2191	Grindstone	18-Mar	Trail #15	tread	0-2	2	240	26.2	26.2			d		at a crossing; N39-16,42,0 W122-43,12,1
2192	Grindstone	18-Mar	Trail #15	tread	0-2	2	210	24.2	24.2			d		at a crossing; N39-16,42,0 W122-43,12,1
2193	Grindstone	18-Mar	Trail #15	tread	0-2	1	280	22.0	22.0			d		at a crossing; N39-16,42,0 W122-43,12,1
2194	Grindstone	18-Mar	Trail #15	tread	0-2	1	300	21.3	21.3			d		at a crossing; N39-16,42,0 W122-43,12,1
2195	Grindstone	18-Mar	Trail #15	tread	0-2	1	280	20.0	20.0			d		at a crossing; N39-16,42,0 W122-43,12,1
2196	Grindstone	18-Mar	Trail #15	tread	2-4	5	60	47.8	47.8			d		at a crossing; N39-16,42,0 W122-43,12,1
2197	Grindstone	18-Mar	Trail #15	tread	2-4	5	80	44.2	44.2			d		at a crossing; N39-16,42,0 W122-43,12,1
2198	Grindstone	18-Mar	Trail #15	tread	2-4	5	76	45.0	45.0			d		at a crossing; N39-16,42,0 W122-43,12,1
2199	Grindstone	18-Mar	Trail #15	tread	2-4	4	100	62.8	62.8			d		at a crossing; N39-16,42,0 W122-43,12,1
2200	Grindstone	18-Mar	Trail #15	tread	2-4	4	115	46.2	46.2			d		at a crossing; N39-16,42,0 W122-43,12,1
2201	Grindstone	18-Mar	Trail #15	tread	2-4	4	105	49.7	49.7			d		at a crossing; N39-16,42,0 W122-43,12,1
2202	Grindstone	18-Mar	Trail #15	tread	2-4	3	140	32.6	32.6			d		at a crossing; N39-16,42,0 W122-43,12,1
2203	Grindstone	18-Mar	Trail #15	tread	2-4	3	160	39.8	39.8			d		at a crossing; N39-16,42,0 W122-43,12,1
2204	Grindstone	18-Mar	Trail #15	tread	2-4	3	150	33.2	33.2			d		at a crossing; N39-16,42,0 W122-43,12,1
2205	Grindstone	18-Mar	Trail #15	tread	2-4	2	220	16.7	16.7			d		at a crossing; N39-16,42,0 W122-43,12,1
2206	Grindstone	18-Mar	Trail #15	tread	2-4	2	240	21.7	21.7			d		at a crossing; N39-16,42,0 W122-43,12,1
2207	Grindstone	18-Mar	Trail #15	tread	2-4	2	220	19.8	19.8			d		at a crossing; N39-16,42,0 W122-43,12,1
2208	Grindstone	18-Mar	Trail #15	tread	2-4	1	250	19.6	19.6			d		at a crossing; N39-16,42,0 W122-43,12,1
2209	Grindstone	18-Mar	Trail #15	tread	2-4	1	300	20.1	20.1			d		at a crossing; N39-16,42,0 W122-43,12,1
2210	Grindstone	18-Mar	Trail #15	tread	2-4	1	300	21.5	21.5			d		at a crossing; N39-16,42,0 W122-43,12,2
3211	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	5	35	42.5		42.5		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3212	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	5	45	49.0		49.0		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3213	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	5	45	45.0		45.0		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3214	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	4	80	32.0		32.0		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3215	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	4	85	33.9		33.9		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3216	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	4	80	31.2		31.2		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3217	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	3	120	29.0		29.0		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3218	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	3	130	29.0		29.0		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3219	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	3	125	28.1		28.1		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3220	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	2	180	27.5		27.5		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring

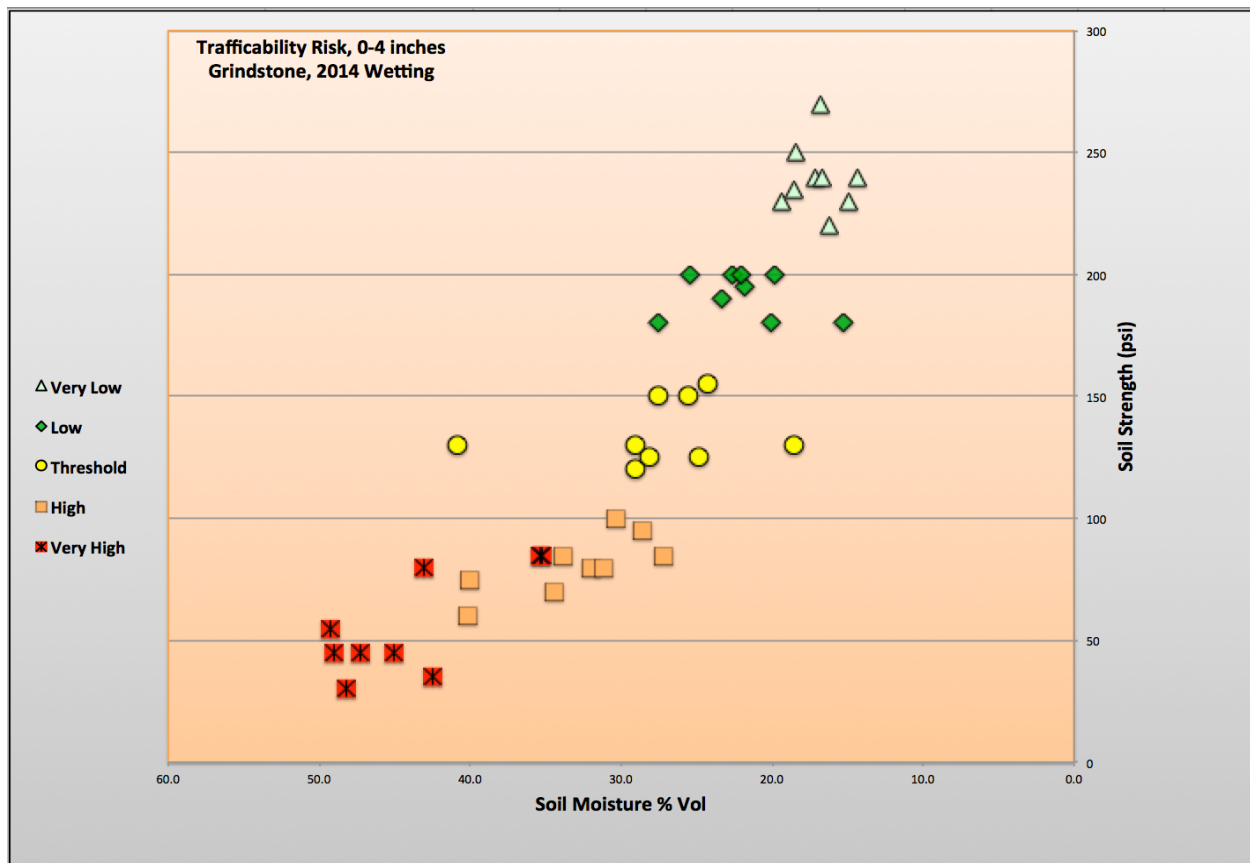
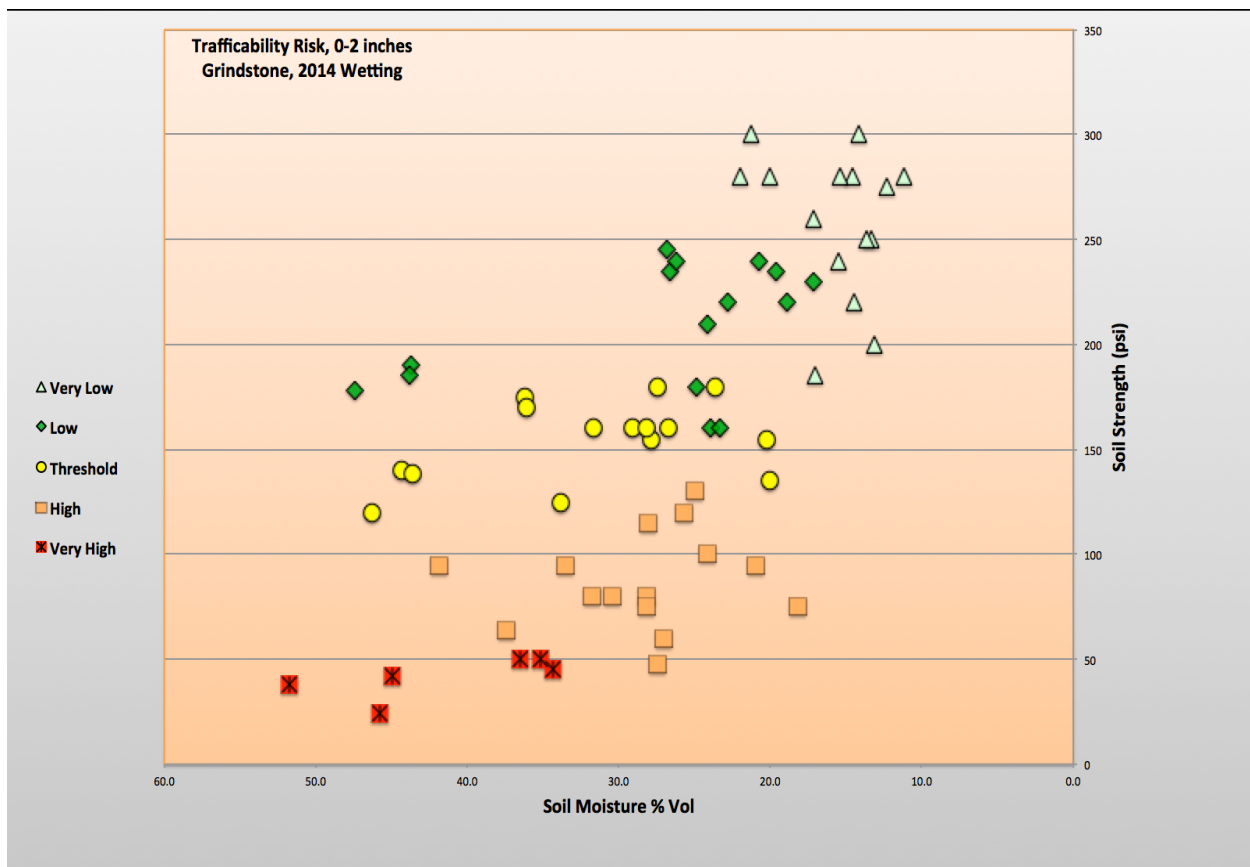
Record	District	Date 2014	Location	Site	Depth	CLASS	psi	% V	Moisture			W/D	Last PPTN	Condition - Soil Type - Notes
3221	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	2	200	25.4		25.4		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3222	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	2	190	23.3		23.3		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3223	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	1	235	18.5		18.5		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3224	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	1	240	17.2		17.2		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3225	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	0-2	1	270	16.8		16.8		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3226	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	5	80	43.1		43.1		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3227	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	5	85	35.2		35.2		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3228	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	5	85	35.4		35.4		d		#12 135-feet E of junction #11; more clay, less gravel; at a spring
3229	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	4	70	34.4		34.4		d		more clay less gravel; at a spring; wet only at surface
3230	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	4	60	40.1		40.1		d		more clay less gravel; at a spring; wet only at surface
3231	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	4	75	40.0		40.0		d		more clay less gravel; at a spring; wet only at surface
3232	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	3	150	27.5		27.5		d		more clay less gravel; at a spring; wet only at surface
3233	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	3	155	24.3		24.3		d		more clay less gravel; at a spring; wet only at surface
3234	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	3	150	25.6		25.6		d		more clay less gravel; at a spring; wet only at surface
3235	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	2	200	22.6		22.6		d		more clay less gravel; at a spring; wet only at surface
3236	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	2	195	21.8		21.8		d		more clay less gravel; at a spring; wet only at surface
3237	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	2	200	22.0		22.0		d		more clay less gravel; at a spring; wet only at surface
3238	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	1	240	16.7		16.7		d		more clay less gravel; at a spring; wet only at surface
3239	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	1	220	16.2		16.2		d		more clay less gravel; at a spring; wet only at surface
3240	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	2-4	1	230	14.9		14.9		d		more clay less gravel; at a spring; wet only at surface
3241	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	5	240	27.3		27.3		d		more clay less gravel; at a spring; wet only at surface
3242	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	5	250	25.8		25.8		d		more clay less gravel; at a spring; wet only at surface
3243	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	5	260	20.8		20.8		d		more clay less gravel; at a spring; wet only at surface
3244	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	4	110	25.5		25.5		d		more clay less gravel; at a spring; wet only at surface
3245	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	4	105	28.2		28.2		d		more clay less gravel; at a spring; wet only at surface
3246	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	4	95	26.4		26.4		d		more clay less gravel; at a spring; wet only at surface
3247	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	3	165	24.1		24.1		d		more clay less gravel; at a spring; wet only at surface
3248	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	3	170	20.5		20.5		d		more clay less gravel; at a spring; wet only at surface
3249	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	3	165	27.9		27.9		d		more clay less gravel; at a spring; wet only at surface
3250	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	2	170	21.0		21.0		d		more clay less gravel; at a spring; wet only at surface
3251	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	2	180	22.5		22.5		d		more clay less gravel; at a spring; wet only at surface
3252	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	2	200	23.2		23.2		d		more clay less gravel; at a spring; wet only at surface
3253	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	1	160	19.5		19.5		d		more clay less gravel; at a spring; wet only at surface
3254	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	1	175	19.7		19.7		d		more clay less gravel; at a spring; wet only at surface
3255	Upper Lake	12-Apr	Trail #12 Penny Pines	dip	4-6	1	170	17.5		17.5		d		more clay less gravel; at a spring; wet only at surface
3256	Upper Lake	12-Apr	Trail #12 Benchmark	dip	0-2	1	170	23.0		23.0		d		Trail #12 Benchmark; DIP OUTLET, drain side; firm, no ruts or tracks
3257	Upper Lake	12-Apr	Trail #12 Benchmark	dip	0-2	1	150	21.8		21.8		d		Trail #12 Benchmark; DIP OUTLET, drain side; firm, no ruts or tracks
3258	Upper Lake	12-Apr	Trail #12 Benchmark	dip	0-2	1	135	27.7		27.7		d		Trail #12 Benchmark; DIP OUTLET, drain side; firm, no ruts or tracks
3259	Upper Lake	12-Apr	Trail #12 Benchmark	dip	0-2	1	250	26.2		26.2		d		Trail #12 Benchmark; dip SHOULDER, on drain side; no ruts, tracks
3260	Upper Lake	12-Apr	Trail #12 Benchmark	dip	0-2	1	270	26.3		26.3		d		Trail #12 Benchmark; dip SHOULDER, on drain side; no ruts, tracks
3261	Upper Lake	12-Apr	Trail #12 Benchmark	dip	0-2	1	200	21.1		21.1		d		Trail #12 Benchmark; dip SHOULDER, on drain side; no ruts, tracks
3262	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	5	45	47.3		47.3		d		this is a mixed site; some readings are away from main site
3263	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	5	30	48.2		48.2		d		this is a mixed site; some readings are away from main site
3264	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	5	55	49.2		49.2		d		this is a mixed site; some readings are away from main site

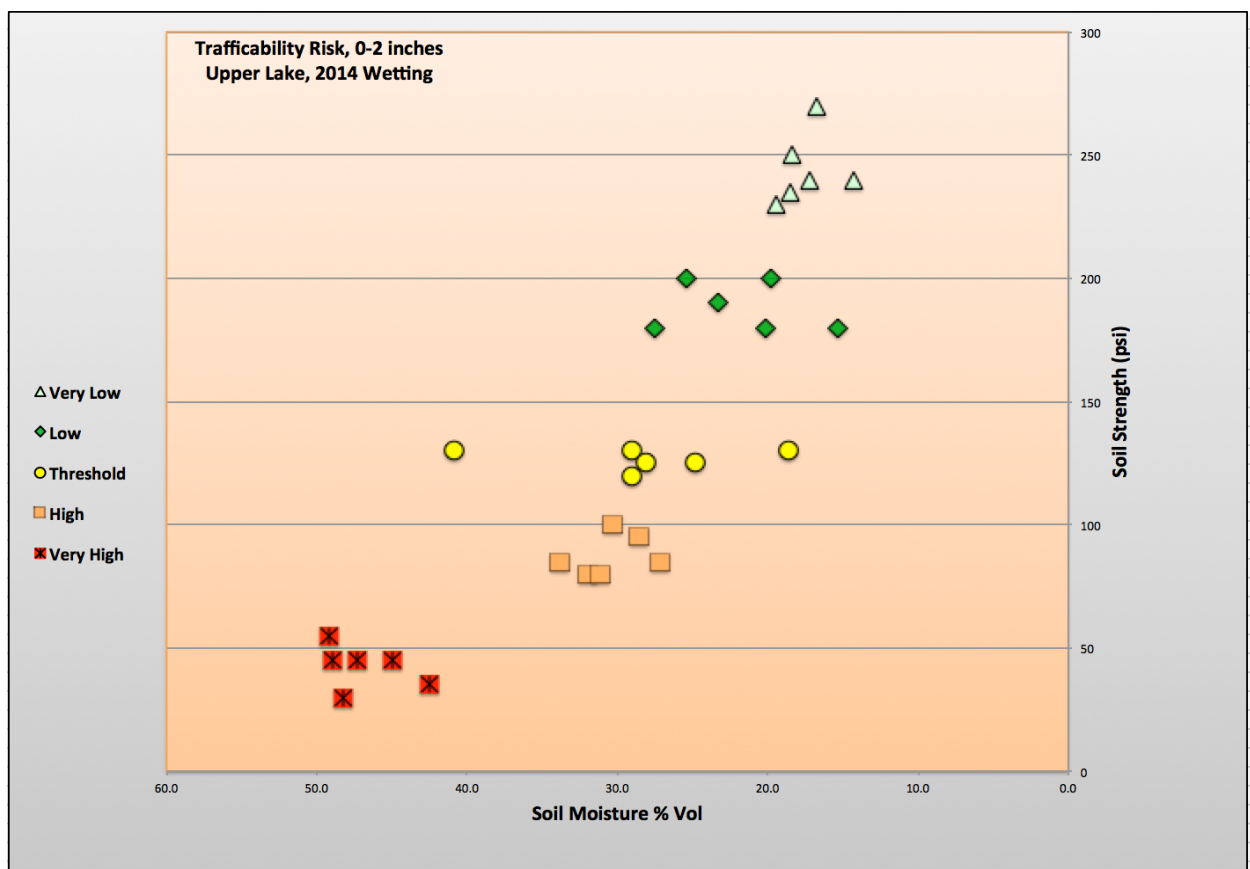
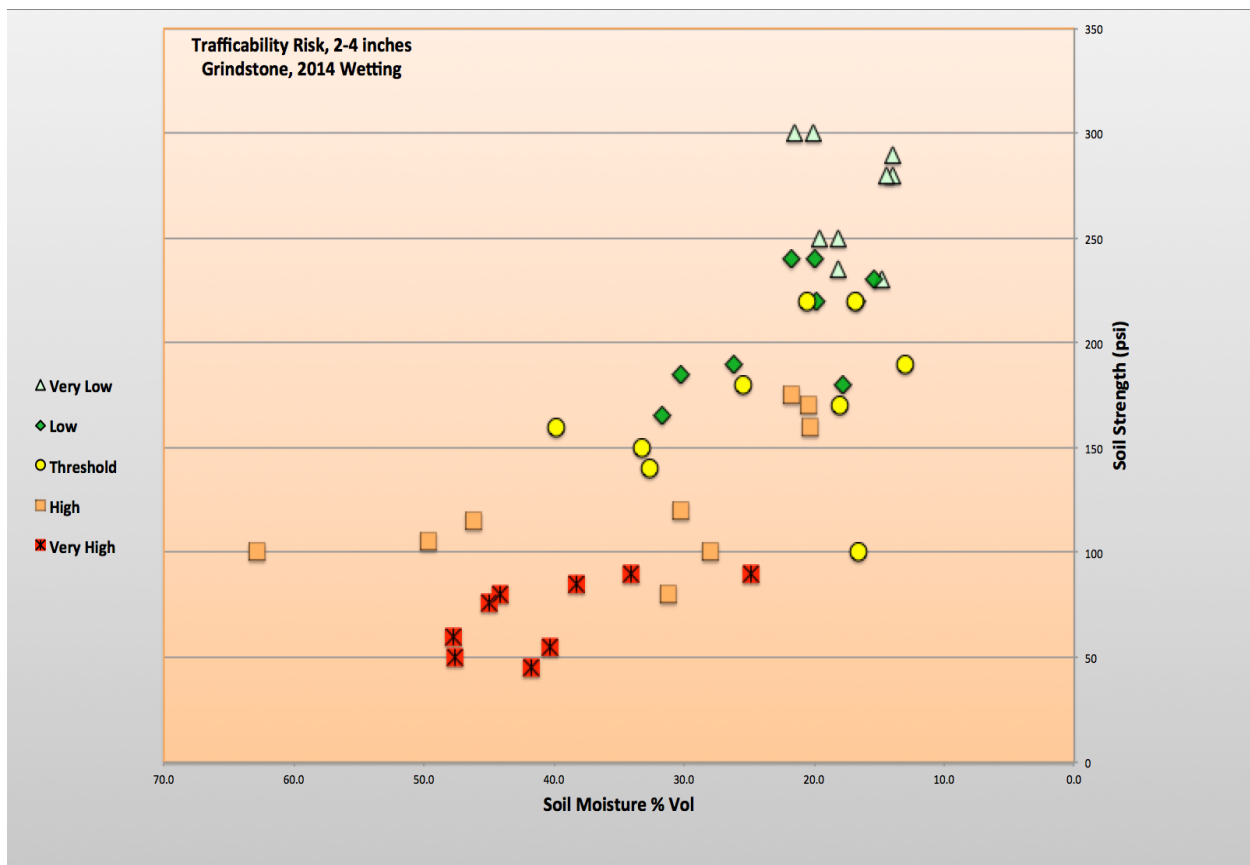
Record	District	Date 2014	Location	Site	Depth	CLASS	psi	% V	Moisture			W/D	Last PPTN	Condition - Soil Type - Notes
3265	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	4	100	30.3		30.3		d		this is a mixed site; some readings are away from main site
3266	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	4	95	28.6		28.6		d		this is a mixed site; some readings are away from main site
3267	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	4	85	27.2		27.2		d		this is a mixed site; some readings are away from main site
3268	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	3	125	24.8		24.8		d		this is a mixed site; some readings are away from main site
3269	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	3	130	40.9		40.9		d		this is a mixed site; some readings are away from main site
3270	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	3	130	18.6		18.6		d		this is a mixed site; some readings are away from main site
3271	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	2	180	20.1		20.1		d		this is a mixed site; some readings are away from main site
3272	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	2	180	15.3		15.3		d		this is a mixed site; some readings are away from main site
3273	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	2	200	19.8		19.8		d		this is a mixed site; some readings are away from main site
3274	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	1	230	19.4		19.4		d		this is a mixed site; some readings are away from main site
3275	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	1	240	14.3		14.3		d		this is a mixed site; some readings are away from main site
3276	Upper Lake	12-Apr	Trail #12, Penny Pines	tread	0-2	1	250	18.4		18.4		d		this is a mixed site; some readings are away from main site
4277	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	5	35	46.4	60.4	46.4		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4278	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	5	40	53.0	60.2	53.0		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4279	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	5	40	55.0	63.1	55.0		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4280	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	4	75	45.1	52.4	45.1		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4281	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	4	75	45.2	46.7	45.2		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4282	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	4	70	45.2	43.2	45.2		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4283	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	3	135	46.4	49.4	46.4		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4284	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	3	140	41.3	48.0	41.3		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4285	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	3	145	38.2	48.8	38.2		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4286	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	2	195	36.7	38.2	36.7		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4287	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	2	205	38.4	38.8	38.4		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4288	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	2	210	37.2	35.2	37.2		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4289	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	1	230	30.0	24.2	30.0		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4290	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	1	245	28.0	25.6	28.0		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4291	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	0-2	1	250	27.9	24.7	27.9		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4292	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	5	85	53.2	64.2	53.2		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4293	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	5	75	55.7	68.2	55.7		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4294	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	5	80	54.1	69.4	54.1		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4295	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	4	115	37.4	39.9	37.4		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4296	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	4	125	40.9	42.6	40.9		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4297	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	4	115	42.0	41.2	42.0		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4298	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	3	130	37.0	36.3	37.0		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4299	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	3	125	40.0	39.6	40.0		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4300	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	3	130	38.0	39.0	38.0		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4301	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	2	190	38.8	35.2	38.8		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4302	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	2	170	30.3	29.4	30.3		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4303	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	2	170	37.7	38.2	37.7		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4304	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	1	230	27.6	26.3	27.6		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4305	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	1	240	31.4	29.2	31.4		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4306	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	2-4	1	235	31.2	29.4	31.2		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4307	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	5	60	65.0	70.2	65.0		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4308	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	5	75	83.0	82.6	83.0		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood

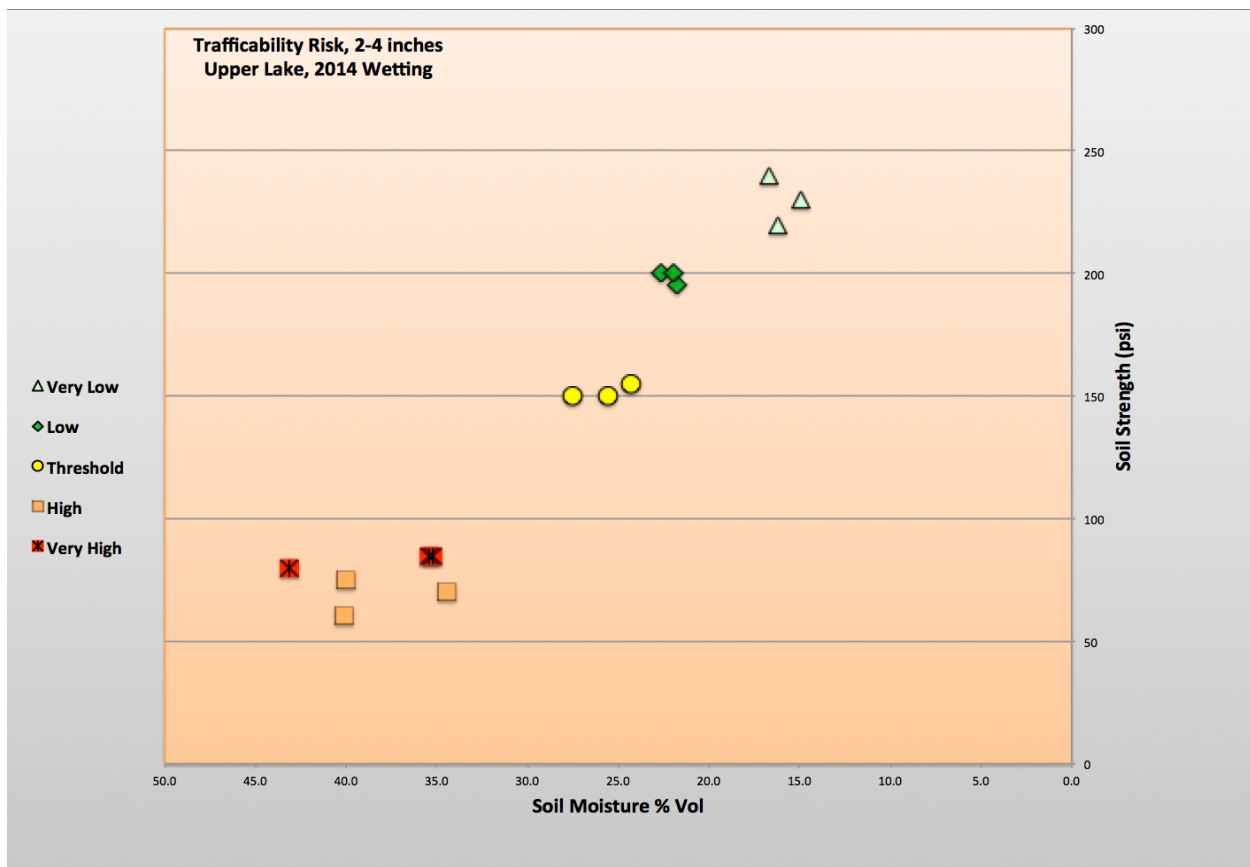
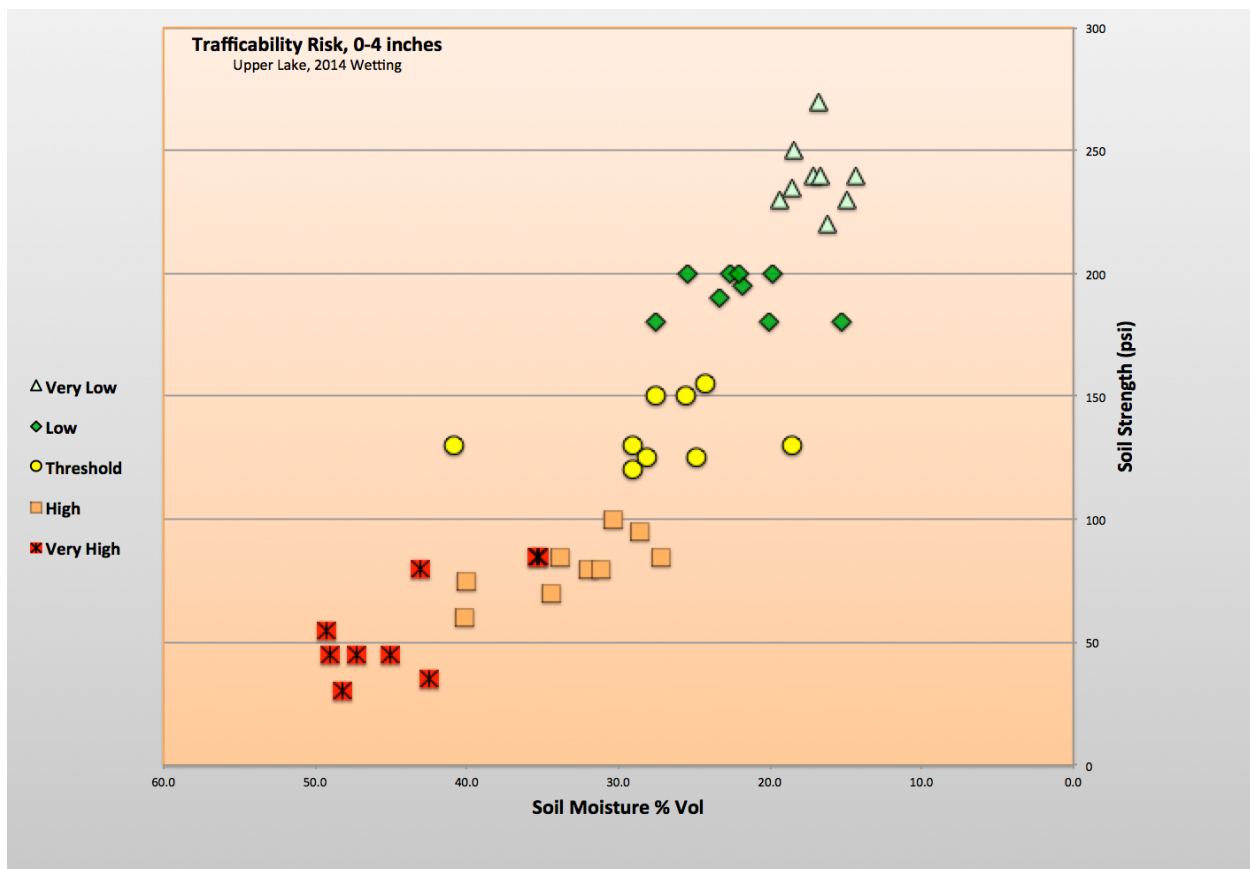
		Date							Moisture			W/D		
Record	District	2014	Location	Site	Depth	CLASS	psi	% V	S150	HH2	delta	Front	Last PPTN	Condition - Soil Type - Notes
4309	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	5	65	58.3	71.8	58.3		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4310	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	4	125	49.7	52.6	49.7		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4311	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	4	90	44.3	47.4	44.3		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4312	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	4	120	38.9	40.2	38.9		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4313	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	3	95	45.0	33.0	45.0		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood; at margin
4314	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	3	100	47.4	48.5	47.4		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood; at margin
4315	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	3	95	43.5	45.6	43.5		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood; at margin
4316	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	2	155	40.8	40.4	40.8		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4317	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	2	140	35.1	40.8	35.1		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4318	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	2	135	34.5	36.9	34.5		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4319	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	1	160	34.1	34.2	34.1		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4320	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	1	140	39.1	36.2	39.1		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4321	Sugar Pine	15-Apr	N39°08.561,W120°46.007	tread	4-6	1	135	42.4	37.0	42.4		d	2 weeks	Trail #7, red clay; almost no rock; some buried wood
4322	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	230	27.3		27.3		d	2 weeks	dip OUTLET, downhill side
4323	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	220	27.4		27.4		d	2 weeks	dip OUTLET, downhill side
4324	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	245	28.1		28.1		d	2 weeks	dip OUTLET, downhill side
4325	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	190	22.3		22.3		d	2 weeks	dip OUTLET, downhill side
4326	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	170	26.9		26.9		d	2 weeks	dip OUTLET, downhill side
4327	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	190	30.4		30.4		d	2 weeks	dip OUTLET, downhill side
4328	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	280	24.8		24.8		d	2 weeks	dip SHOULDER, downhill side
4329	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	270	23.8		23.8		d	2 weeks	dip SHOULDER, downhill side
4330	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	280	19.2		19.2		d	2 weeks	dip SHOULDER, downhill side
4331	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	220	25.0		25.0		d	2 weeks	dip SHOULDER, downhill side, dry layer only 3/4 inch deep
4332	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	230	31.6		31.6		d	2 weeks	dip SHOULDER, downhill side, dry layer only 3/4 inch deep
4333	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	220	34.0		34.0		d	2 weeks	dip SHOULDER, downhill side, dry layer only 3/4 inch deep
4334	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	200	19.8		19.8		d	2 weeks	dip OUTLET, downhill side; scraped away 1/2-in of fluff and needles
4335	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	210	29.0		29.0		d	2 weeks	dip OUTLET, downhill side; scraped away 1/2-in of fluff and needles
4336	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	230	26.0		26.0		d	2 weeks	dip OUTLET, downhill side; scraped away 1/2-in of fluff and needles
4337	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	240	34.1		34.1		d	2 weeks	dip OUTLET, downhill side; scraped away 1/2-in of fluff and needles
4338	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	230	27.5		27.5		d	2 weeks	dip OUTLET, downhill side; scraped away 1/2-in of fluff and needles
4339	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	235	32.3		32.3		d	2 weeks	dip OUTLET, downhill side; scraped away 1/2-in of fluff and needles
4340	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	250	11.4		11.4		d	2 weeks	dip SHOULDER, downhill side; top 1.5-inch well-compacted
4341	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	220	12.1		12.1		d	2 weeks	dip SHOULDER, downhill side; top 1.5-inch well-compacted
4342	Sugar Pine	15-Apr	at the remote sensing site	dip	0-2	1	240	12.7		12.7		d	2 weeks	dip SHOULDER, downhill side; top 1.5-inch well-compacted
4343	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	240	26.4		26.4		d	2 weeks	dip SHOULDER, downhill side
4344	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	245	22.6		22.6		d	2 weeks	dip SHOULDER, downhill side
4345	Sugar Pine	15-Apr	at the remote sensing site	dip	2-4	1	230	24.0		24.0		d	2 weeks	dip SHOULDER, downhill side

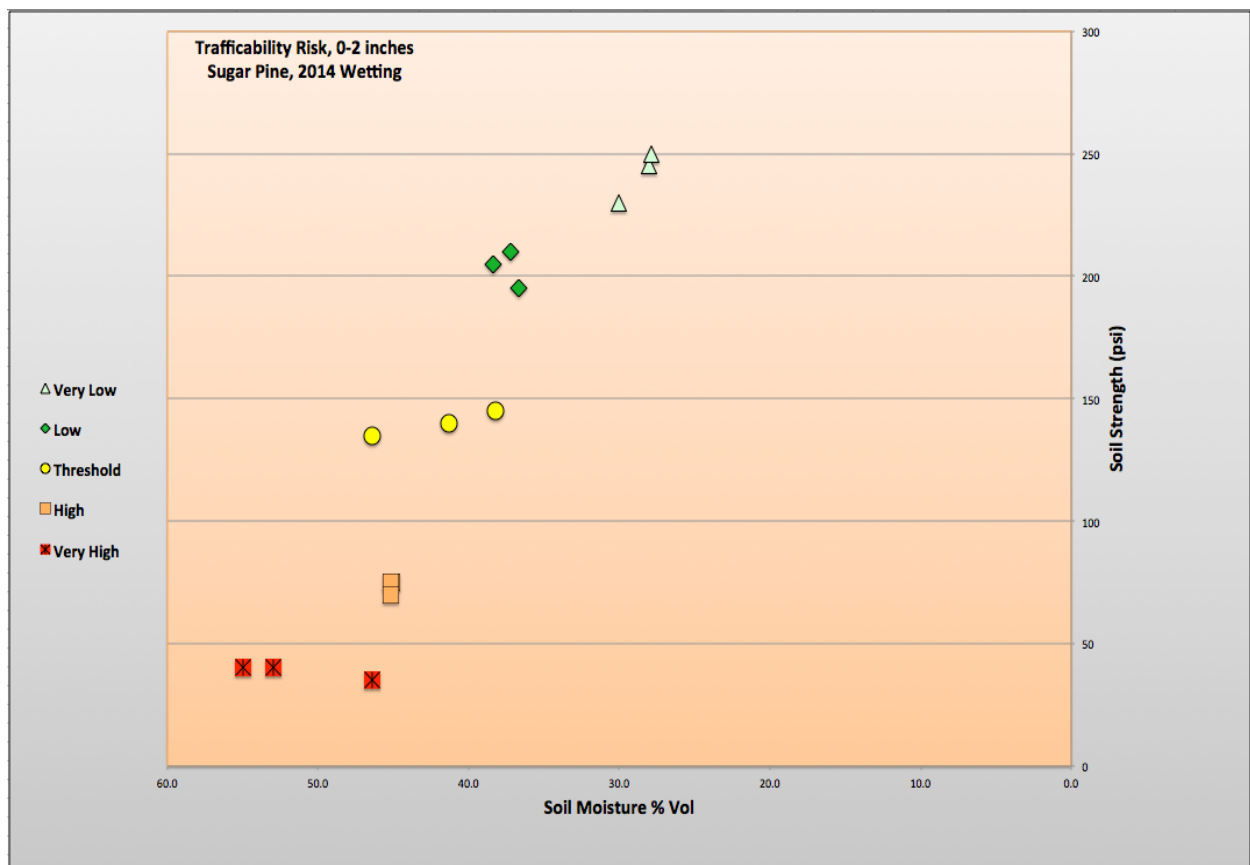
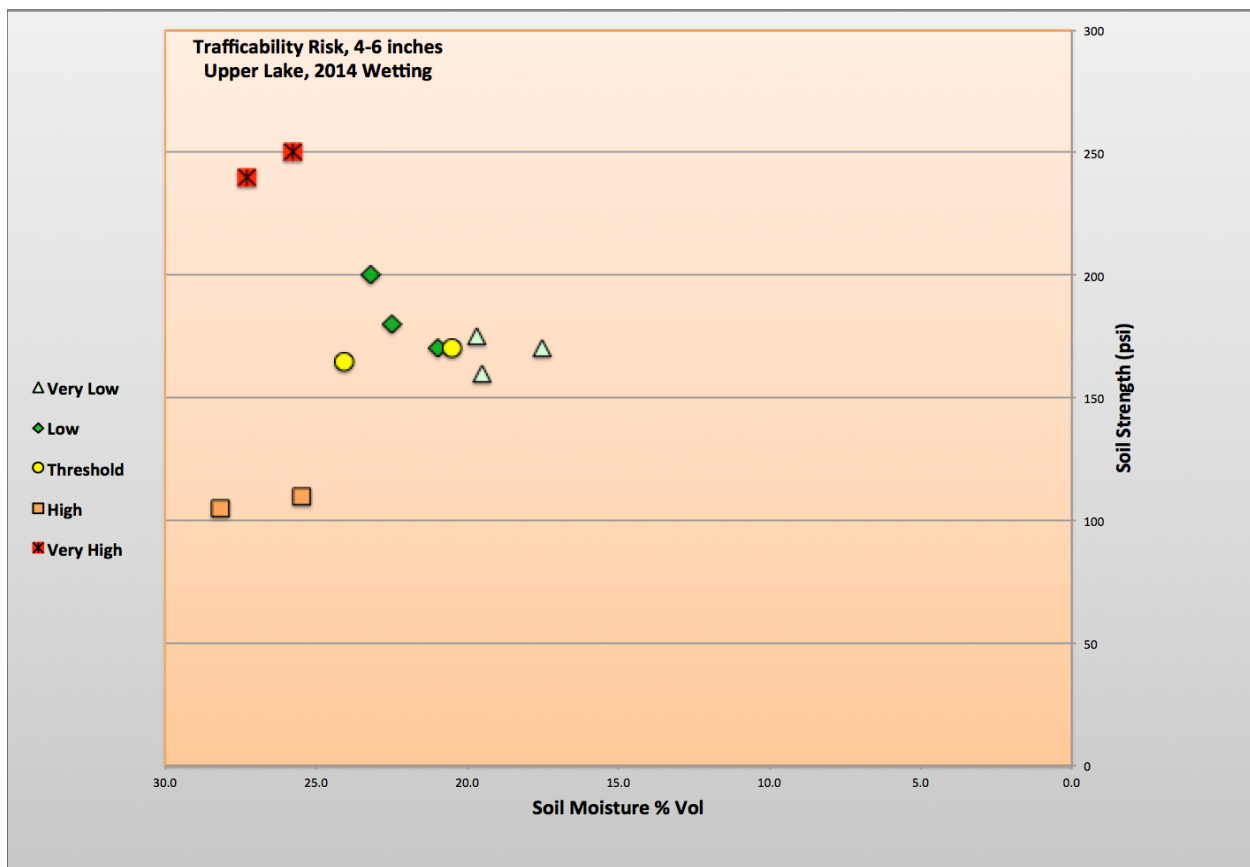


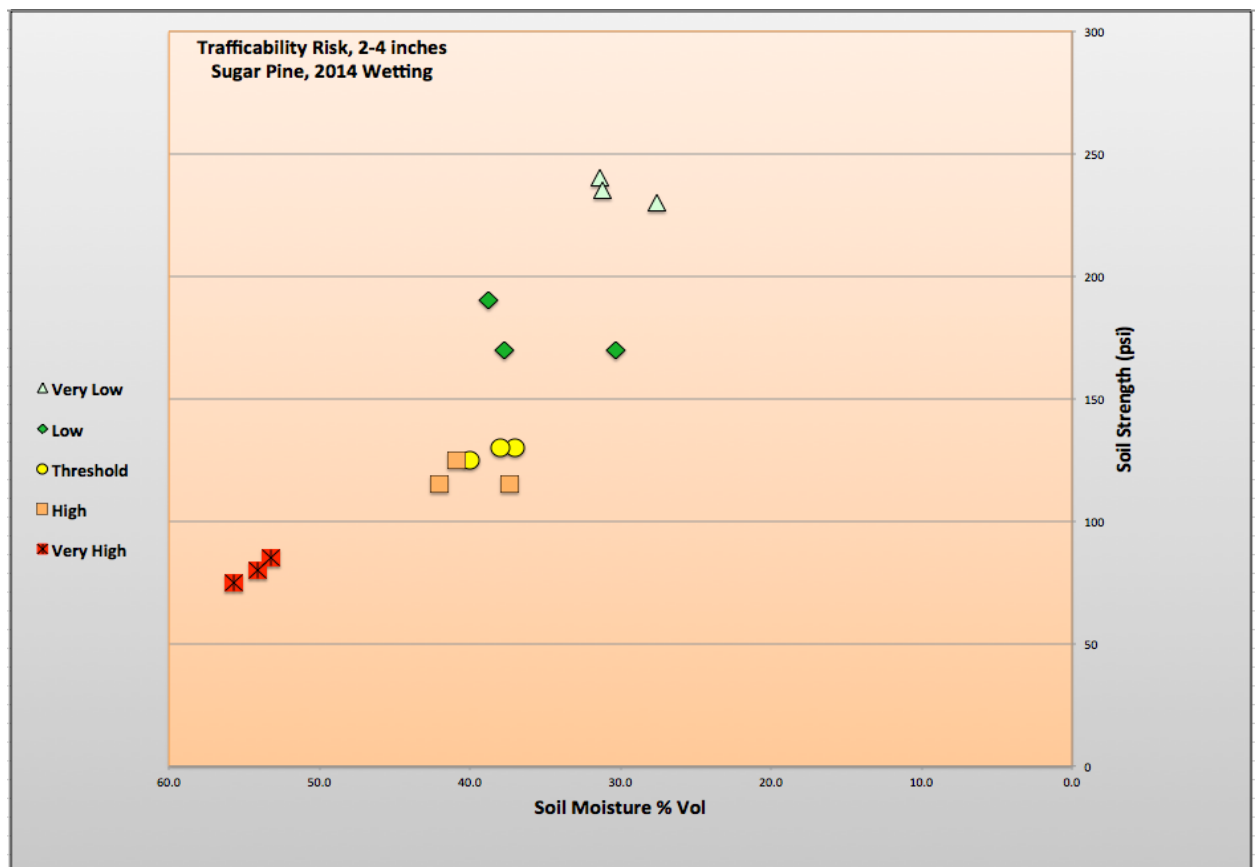
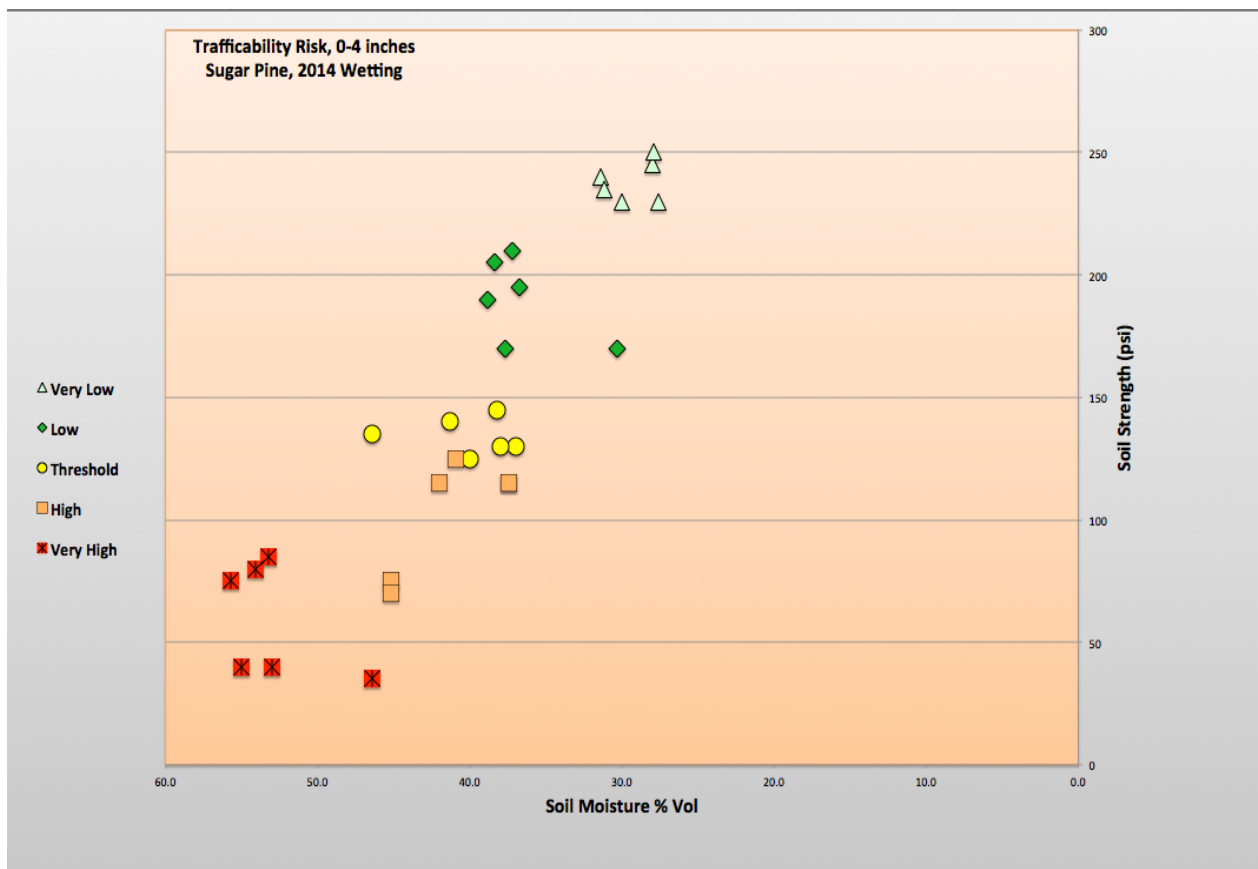


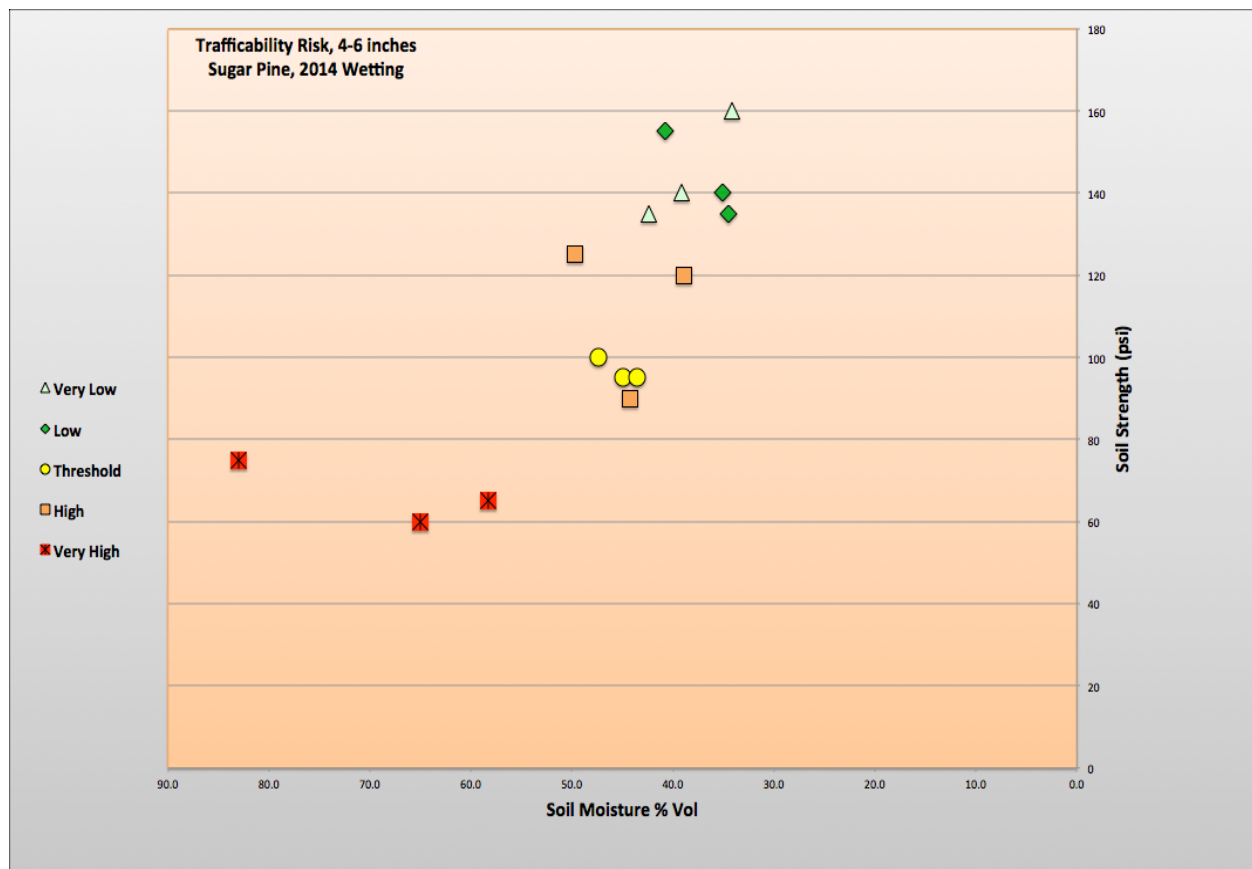












Acknowledgements

The following individuals assisted with data collection, provided financial support, or otherwise provided encouragement since fieldwork on this approach to wet-weather management began in April 2008. Special recognition is due to Alex Janicki, who came up with the original concept, and to Cam Lockwood and Kathleen Mick who secured the funding to conduct the studies.

Katherine Albers	Jason Morton
Don Amador	Warren Oja
Laura Bates	Jeff Olson
Terry Brennan	Kathleen Phelps
Mike Burmann	Matt Piper
Joe Chavez	Phil Ray
Alex Janicki	Sarah Ridenour-Chamberlain
Scott Johnson	Alicia Sanchez
Cam Lockwood	Steve Thompson
Lloyd McWilliams	Mark Tracy
Kathleen Mick	Bruce Witcher
Mark Miller	